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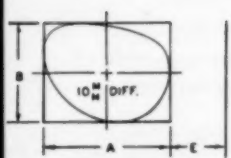

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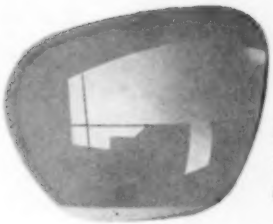

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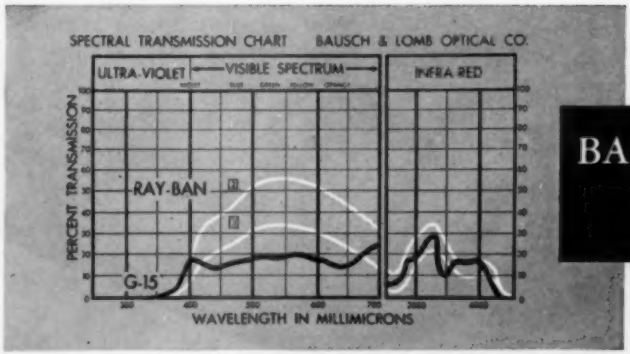

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THE RELATIONSHIP BETWEEN MEASLES AND MYOPIA*

Monroe J. Hirsch†
Ojai, California

It is generally believed that some relationship exists between such childhood febrile diseases as measles and the development of myopia. Duke-Elder[1] sums up this concept as follows:

> It has long been observed that myopia has a habit of appearing or increasing in periods of ill-health or after disease: the common belief that it starts in youth with measles or some such childish febrile disease is not without truth.

This same belief that myopia, at least in certain individuals, may be a result of a disease like measles has also been stated by Edridge-Green[2] who felt that measles had a specific action in softening the sclera and by Claiborne[3] who felt that after an attack of measles there is a lowering of vitality, a congestion of the tissue, and a weakening of the sclera which is a causitive factor in the production of the myopic state. Some other authors who have expressed the belief that myopia is associated with general debilitating or febrile diseases are Harman,[4] Harrison,[5] Lindner,[6] Priestley Smith,[7] Sonder,[8] and Keith.[9] In an atempt to classify myopia, Harding[10] suggested as one form of myopia an infantile pyretic type. This he described as follows:

> *Infantile Pyretic.* I suggest that a special division should be made for those cases in which, as the name suggests, myopia develops following an attack of the usual infantile fevers. Sir Arthur Keith says that following measles, scarlet fever and similar febrile illnesses, the scleral tissues become charged with toxins, and, in consequence, the fibrils are weakened. Too many such cases have been reportd for this factor to be ignored, including cases occurring where the child is the only member of a family to develop myopia, and also the only child to have suffered severely with one of these fevers.

As is so often the case in the field of refraction and particularly in myopia, the number of references to the supposed existence of a phenomenon is not an index of its validity. The references cited above are, for the most part, the result either of observation of certain patients and speculation as to the meanings of these findings, or simply a reiteration of the speculations of some earlier investigator. Experimental results, and particularly controlled experimental results do not seem to be the basis for the hypothesis that measles and myopia are related.

It has occurred to many who have rejected the hypothesis that a

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†Optometrist, Ph.D., Fellow, American Academy of Optometry.

simple relationship cannot be involved. Almost all children have measles at some time. How, then, can it be the simple cause of an anomaly like myopia which only affects a small number of children? It is this stumbling-block which has kept the hypothesis of measles as a cause of myopia from gaining any wide acceptance. However, if two possibilities are recognized, the hypothesis may be shown to rest upon firmer footing. It is possible that (a) there may be many types of myopia, with that caused, or predisposed, by measles being only one type and that (b) measles may be a predisposing cause only if the disease is contracted at certain ages.

Both of these possibilities are in conformity with current knowledge. Few authors today hold to the belief that all myopia results from the same cause. Harding,[10] for example, postulated several types of myopia. The concept that myopia is merely a symtom of a series of different clinical states has been expressed earlier by Hirsch[11] and is here reaffirmed. All existing evidence seems to point in this direction, and it is our belief that research in this field will be enhanced by the acceptance of this assumption.

The second possibility is equally acceptable. It is now clearly established that rubella of the mother occurring during the first three months of pregnancy leads to certain eye defects in the infant, while the same disease in the mother at any other period in pregnancy has no such effect. The effect of measles on the development of myopia may be similar, and measles at certain ages may predispose a person toward one type of myopia, while measles at another period in the child's life may have no effect on refraction.

Much of the myopia which exists is probably due to an anomaly of growth. In many children the eye attains adult size quite early. For example, the average curve, presented by Weymouth and Hirsch,[12] for axial length size at various ages becomes asymptotic at about the age of nine of ten. Stoddard[13] has suggested that the period just prior to that characterizing the completion of general growth might find the eye most vulnerable to growth disturbances. Thus, if a relationship held, one might expect measles which occurred immediately prior to the ninth year to be most likely to exert some effect on the total refraction.

PRESENT INVESTIGATIONS

Although the study to be reported leaves much to be desired insofar as controlled experimentation is concerned, it does offer a statistical approach to the problem and evidence which, while not conclusive, is certainly suggestive enough to warrant further investigation. The data were accumulated by the author in conjunction with another larger study

of the sociology of refractive states.*

The technique employed was simple. The refraction was determined retinoscopically by the author's method[16] and the average (of the two eyes) equivalent sphere was used as a measure of the refractive state. The measles data were obtained by a questionnaire filled out by the subjects and their parents. The test was administered to all students at a junior high school in suburban Los Angeles. The subjects were between 13 and 17 years of age. Of 600 students in the original sample, approximately 400 complete records were obtained. The respondent was requested to place next to a list of diseases the age at which he had had each disease. One of the diseases listed was measles. Thus, the basic data for the present study are two simple variables: (a) the refractive state as measured by retinoscopy and expressed by the average equivalent sphere, and (b) an answer to the question, "Did you ever have measles and, if so, at what age?"

Clearly, the method of obtaining information about the second variable, the age at which the child had measles, leaves much to be desired. The memory of parents as to the year during which their children had measles is probably poor, and such differentiations as "German measles," "three-day measles," and "red measles" present further difficulty. Since a number of questionnaires were not filled out, the sampling is not truly random. On the other hand, none of these weaknesses of technique should lead to systematic errors. There is no reason why the parent of a myopic child should exaggerate the age at which that child had measles any more than the parent of a child with any other visual status. Thus, the technique for obtaining one variable has many sources of error, but none of these is in any way related to the other variable and, hence, the data are usable in the present context.

The refractive data are both reliable and valid. Since the age of the subjects was 13 to 17 years, it was felt that the vast majority of the children who would become myopic would already be manifesting some degree of the anomaly.

Of the approximately 600 questionnaires sent out, about 400 completed forms were returned; 369 of these contained some answer to the

*The primary study was conducted in 1953 by the author and Melvin Nadell, at that time a student in the optometry curriculum and simultaneously a candidate for the Ph.D. degree in sociology at the University of Southern California. The major portion of the investigation was to serve as the basis for Nadell's dissertation and dealt with numerous sociological variables as they related to visual status. These data were published in 1954 as a dissertation by Nadell[14] and will also form the basis for a series of papers by him and the present author, the first of which[15] has already appeared.

question about measles. Of this number, 38 reported having had measles twice and were omitted from the study. In these instances, there is some question as to whether both events were truly measles: also, such data are difficult to handle statistically. It was felt that the exclusion of these at the outset would not create a serious sampling error. Of the remaining, only 17, or approximately 5 per cent, reported never having had measles. This number may be too low since some of those omitted may not have had the disease but did not answer the question by circling the item "never." Whatever the case, the number of children in the population who never had measles is not great and is probably no more than ten, or at most 15, per cent. These 17 children, therefore, are included in Table I which presents the raw data but are omitted in subsequent calculations. Thus, the individuals yielding the basic data for statistical analysis are 314 children, i.e., those who reported having had measles at some age between one and fourteen.

TABLE I

RAW DATA—Each item is Number of Cases

Category	Myopia	Low Myopia	Non-Myopia	
Criterion	—1.00 D. or greater	—0.01 D. to —0.99 D.	Plano to +5.00 D.	Total
Age of onset of measles				
1	0	1	8	9
2	0	0	6	6
3	0	3	14	17
4	2	5	36	43
5	1	2	49	52
6	6	6	46	58
7	6	4	31	41
8	7	4	25	36
9	1	2	18	21
10	1	1	11	13
11	0	1	8	9
12	0	0	6	6
13	0	0	1	1
14	0	0	2	2
Sub-total	24	29	261	314
Never had measles	1	2	14	17
Total	25	31	275	331

The raw data are presented as Table I. For purposes of statistical analysis, the chi square method was chosen as the most applicable. The data were grouped by age so as to have at least two individuals in each category. Two different criteria for myopia were utilized. In Table II the myopia category would be defined as "all individuals with any minus refractive state." In Table III myopia would be defined as "myopia of 1.00 D. or more." The value of chi square obtained from Table II is

TABLE II*

Age of onset of measles	Myopia (all in excess of —0.01 D.)	Non-Myopia (plano through highest hyperope)	Totals
3	4	28	32
& under	(5)	(27)	
4	7	36	43
	(7)	(36)	
5	3	49	52
	(9)	(43)	
6	12	46	58
	(10)	(48)	
7	10	31	41
	(7)	(34)	
8	11	25	36
	(6)	(30)	
9	3	18	21
	(4)	(17)	
10	3	28	31
& over	(5)	(26)	
Total	53	261	314

13.35 which, for seven degrees of freedom, corresponds to a probability of between 0.05 and 0.10. The chi square for Table III is 16.52 which, for four degrees of freedom, corresponds to a probability of between 0.01 and 0.001.

Thus, when the data are grouped so that all negative refractive states are defined as myopia, no significant relationship is observed, but when myopia is defined as refractive states of —1.00 D. and more, then a statistically significant probability is obtained. Inspection of Table III reveals that this significant chi square rests upon there being more myopes than expected in the six, seven, and eight year age group and fewer than expected in the "five and under" group and the "nine and over" group. This suggested one final regrouping.

In Table IV, those individuals who had measles during their sixth,

TABLE III

Age of onset of measles	Myopia (all in excess of —1.00 D.)	Non-Myopia (—0.99 D. through hyperopia)	Totals
5	3	124	127
& under	(10)	(117)	
6	6	52	58
	(4)	(54)	
7	6	35	41
	(3)	(38)	
8	7	29	36
	(3)	(33)	
9	2	50	52
& over	(4)	(48)	
Total	24	290	314

*In Tables II, III and IV the numbers indicate observed subjects, while those in parentheses indicate the expecteds based on chance.

TABLE IV

Age of onset of measles	Myopia (all in excess of —1.00 D.)	Non-Myopia (—0.99 D. through hyperopia)	
6, 7, & 8	19	116	135
	(10)	(125)	
All others	5	174	179
	(14)	(165)	
Total	24	290	314

seventh, and eighth year are compared to those individuals who had measles at all other ages. They are compared with regard to which children developed more than 1.00 D. of myopia and which children became hyperopic, emmetropic, or developed less than 1.00 D. of myopia. For Table IV the chi square is 15.02 which, for one degree of freedom, corresponds to a probability of less than 0.001.

Before considering the interpretation of these findings, two serious shortcomings should be mentioned. First, the method of grouping leaves much to be desired. There is a certain degree of arbitrariness in the grouping both by age and by refractive state. Second, although the sample was not particularly small, the number of individuals with myopia of more than 1.00 D. was only 24. While it is true that the significantly low probability value indicates that the sample is large enough, one would feel much safer were the sample three or four times larger.

The interpretation which may be placed upon these data is quite simple. Those children who have measles during their sixth, seventh, or eighth year seem to be much more likely to develop myopia in excess of 1.00 D. than children who have measles at other ages. To be exact, 14.1 per cent (19/135) of the children who had measles during their sixth, seventh, or eighth year developed myopia in excess of 1.00 D., while only 2.8 per cent (5/179) of the children who had measles at other ages developed myopia of similar degree. Thus, a child who has measles at six, seven, or eight is five times as likely to grow up to have more than 1.00 D. of myopia than is a child who does not have measles during this period.

At the time the study was conducted, the children were between 13½ and 17 years of age. Since the age of the child at the time the study was conducted might be a spurious factor, the average age of the group of emmetropes and hyperopes, low myopes, and myopes in excess of 1.00 D. were calculated. For the emmetropes and hyperopes, the average age at the time this study was conducted was 15.45 years; the group of low myopes, 15.36 years; and the group who had myopia

in excess of 1.00 D. was 15.33 years. There was, then, less than a two months age difference between the average age for these groups, and it is felt that this was not a spurious factor.

One might also wish to know the degree of myopia which was exhibited by those 24 individuals described as having myopia in excess of 1.00 D. Eleven of these individuals had myopia between 1.00 and 2.00 D., nine had myopia between 2.00 and 3.00 D., two had myopia between 3.00 and 4.00 D., two had myopia between 4.00 and 5.00 D., and one had myopia between 5.00 and 6.00 D.

It has been stated that the data here presented, while subject to criticism both of methodology and of statistical treatment, nonetheless indicate a relationship between the development of myopia of between 1.00 D. and 6.00 D. and the incidence of measles at ages six, seven, and eight. This fact seems to tie in well with the general theoretical considerations discussed earlier. Hirsch[17] in an earlier study analyzed the distribution curve of refractive errors and postulated, on the basis of this analysis, the existence of at least three types of myopia. The first of these, myopia of low degree (alpha group), was believed to be due to normal variations in growth. The second of these, myopia between 1.00 D. or 2.00 D. and 5.00 D. or 6.00 D. (beta group), was believed to be due to some form of growth irregularity. The third group, myopia above 6.00 D. or 7.00 D. (gamma group), was believed to include those individuals with congenital myopia, degenerative myopia, possibly hereditary myopia, and other forms of the anomaly. Hirsch urged that the clinical nature of each of these groups be studied further to determine what causal factors might be involved in each. The present study would seem to indicate that at least some of those myopes in the beta, or middle, group have myopia which is associated with an attack of measles at a period in their development when the disease exerted some adverse effect upon the eye.

The results here presented are particularly attractive because if they are indicative of a real phenomenon, then a method for prevention of some myopia immediately presents itself. If the results of the present pilot study are substantiated by further investigation and if measles during the sixth, seventh, and eighth year result in one child in every seven (14 per cent) becoming myopic, then it might become desirable either to medically induce a mild case of measles in all children before they reach the age of five, if this can be done successfully, or to prevent measles from being contracted during the critical ages. This would markedly reduce the incidence of at least one form of myopia.

Despite the high level of statistical significance of the present results,

their conformity with current hypotheses of myopia and of growth, and the possibility of preventing some myopia in the future, we must insist that the present study not be regarded as conclusive. Its value lies only in its being considered a pilot study which suggests the design for a future, more definitive, study and one which will either disprove or substantiate these findings.

With regard to future studies, it may be noted that data of this sort are not easy to obtain. If older people are questioned as to the age at which they had measles, they are seldom able to remember with any degree of accuracy. On the other hand, the subjects must be no younger than those in the present study since most myopia does not develop until approximately this age. It is our belief that a group of high school or college age students is the best group to study. The ideal method, of course, would be to note the age at which children had measles, wait until they were grown, and note which children became myopic and which did not. Such data will be available from the author's Ojai Longitudinal Study[18] in five to seven years. In the meantime, however, the present hypothesis can be tested if other investigators study the problem in the same manner as the present study but on other populations. If this is done, it is suggested the same criteria be used: Namely, "1.00 D. or more" as the definition of myopia and ages six, seven, and eight as the ages compared to the others.

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CORRESPONDENCE

STEREOSCOPIC VISUAL ACUITY

To the Editor:

The editorial by Hirsch* prompts me to make a comment. Perhaps the premise on which Hirsch based his paper is not accurate, viz., that the stereoscopic manner of taking visual acuities is more natural than by occlusion of either eye. I know of no optometrist who records stereoscopic acuities as his one and only measurement of visual acuity. Many will take such a finding and record it as part of the "visual skills," adding a Snellen acuity at some other time during the refraction.

It is a fact that Snellen acuity measurements are the only ones carried out during routine screenings in many schools and industry. Under such circumstances, the acuity of one eye, while the other is occluded, provides a purely academic finding, i.e., that the eye is capable of certain discrimination, but gives no hint as to whether this discrimination is actually achieved during binocular vision. Take the example of the anisometrope of 1.00 D., his hyperopic eye should achieve the same 20/20 vision (excluding amblyopes or presbyopes) as the emmetropic eye. Yet, when fusing a stereoscopic brackground, there will be no alternation of accommodation and either one or the other eye will show a reduction of acuity. There are, of course, a number of other causes for blurring or suppression which will not be apparent during occlusion.

On the other hand a small amount of astigmatism which may cause difficulties with discrimination of letters on the Snellen chart, will allow the patient to pass the "dot on square" stereo test 100%. This, however, is due to the nature of the target rather than the instrumentation.

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*Monroe J. Hirsch. Visual Acuity. Am. J. Optom. & Arch. Am. Acad. Optom. 34.4.209-212. 1957.

AMBLYOPIA AND THE STILES-CRAWFORD EFFECT*

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INTRODUCTION

In this paper, a study of the relationship between amblyopia and the orientation of the retinal receptors will be presented. This report is a preliminary study since it represents only a starting point for research in this direction. It should be emphasized at the outset, that the claim is not made that all amblyopia is related to the retinal direction effects to be described below.

Before proceeding, it will be best to define amblyopia and to provide background information on the Stiles-Crawford effect. Amblyopia has been defined as "a lack of normal vision which is not ascribed to a refractive error to active pathology."[1] However, the concepts presented in this paper may be extended to applicable cases of active pathology.

Stiles and Crawford[2] in 1933 found that light entering the pupil centrally was perceived brighter than light entering the pupil peripherally. The value η, proposed by Stiles and Crawford, designates relative luminous efficiency for a ray entering the entrance pupil of the eye at any point at a specific radial distance, along some given meridian, from the center of the entrance pupil (or other reference point).

$$\eta = \frac{Br}{Bro}$$

The Stiles-Crawford effect is measured by means of successive luminance matches. Br is the luminance of the comparison field required to make it match the test field in brightness when the test beam enters the entrance pupil at a radial distance, r, from the reference point at which $r = o$. Bro is the value of Br when $r = o$.

Obviously, relative luminous efficiency, η, is a function of r and similarly must be a function of the angle at which incident energy strikes the retina. From Gullstrand's schematic eye the following simple relationship may be derived relating position in the entrance pupil and angle of incidence, Θ, (or acceptance angle) at the retina.

$$\tan \Theta = 0.045r$$

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For small angles this reduces to

$$\theta = 0.045r$$

As pointed out by several authors, this corresponds roughly to 2.5° per millimeter.

Figure 1 shows a plot of the data for a subject exhibiting a normal Stiles-Crawford curve. Central fixation was employed and the target was limited to the fovea. It will be noticed that the curve is not centered in the pupil, and that sensitivity falls off rapidly as the retinal angle of incidence becomes increasingly oblique.

It is not the intent of this paper to review all work which has been done on the Stiles-Crawford effect, but rather to review pertinent advances relating to the problem at hand. In general, the following information is known:

1. The Stiles-Crawford effect is mediated at the retina. The most recent proof of this was an experiment conducted by Donner and Rushton[3] who measured a single fiber response on the exposed retina of a frog. They determined luminous efficiency curves by varying the angle of incidence of a narrow beam of light.

2. The effect is mediated by the receptor elements as demonstrated by the fact that completely different patterns are obtained under conditions of photopic and scotopic illumination.[4, 5] Until recently, it was thought that there was no Stiles-Crawford effect in rods. However, Flamant and Stiles[6] in a case to be discussed at a later point demonstrated a rod function.

3. The Stiles-Crawford effect is essentially not dependent on level of luminance except in the mesopic range (or transition range between scotopic and photopic luminance levels).[5, 6, 7] This implies that it is probably a physical phenomenon mediated either by the optics or configuration of the receptor, and/or possibly by some molecular orientation of the photopigments or other elements.

4. The effect varies little with wavelength, but perceived hue changes with angle of retinal incidence.[8]

5. The maximum of the Stiles-Crawford curve shifts in position with the passage of time. Stiles[8] believes this indicates a gradual shearing over the end organs.

6. O'Brien[9] has shown by means of a simple test that a large group of receptors may be oriented differently from neighboring groups. In essence, he moved a pinhole rapidly across the pupil. It is found that for some subjects for one orientation of the pinhole one region of the field looks darker than an adjacent region while the relative sensitivities of the regions reverse for a second position of the pinhole in the pupil.

This indicates that adjacent receptors or receptor groups may be differently oriented with regard to the pupil.

In recent years most research activity in this direction has been largely from a theoretical point of view. However, independent of theoretical construct, all current theories describing directional sensitivities of the retina depend entirely on the receptor elements being directionally oriented.

O'Brien[10] has postulated that the ellipsoid of the cone acts as a light funnel, but this funneling action depends on the obliquity of incidence. Toraldo[11] has likened the cone to a dielectric antenna due to many similarities such as morphology, scatter and radiation pattern. The author[12] recently has proposed that the effect is related to the angle amplification properties of the cone. The current research problem largely deals with finding methods to further investigate the intracellular aspects of the receptor units.

THEORETICAL DEVELOPMENT

The reader may ask, what has all this to do with amblyopia? First let us remember that the outer segments of the layer of rods and cones are not attached to the pigment epithelium layer and that this is the usual site of retinal detachment, largely due to the nature of embryonic development. Is it not possible for these elements to become tilted or sheared over relative to the pupillary aperture? Referring to Figure 1, this would logically result in the entire distribution being tilted over to the side. If this were the case, one would predict this eye to be less sensitive to light since the direction of maximum sensitivity of the retinal receptors would not be pointed in the direction of incidence of the greater portion of the light. Indeed, even this normal subject manifests a slight tilt, as do most normal observers. Marked tilt would in turn reduce acuity, since if sensitivity is reduced absorbed energy is reduced and as is well known, acuity is dependent upon this factor. Further, if the receptors are markedly tilted such that a ray incident from the center of the pupil passes through, for example, two receptors rather than one, the grain would be cut effectively in half and acuity would drop accordingly. In this instance one might expect the difference in acuity to be directional.

If one considers the problem of differential sensitivity between the amblyopic and normal eyes, one cannot assume this to be a simple neutral density filter effect such as a constant difference in the percent of the light absorbed for a given size pupil. One must also consider the effect of stray light in the eye. Boynton, Enoch and Bush[13] demonstrated by physical measurement that approximately ten times more

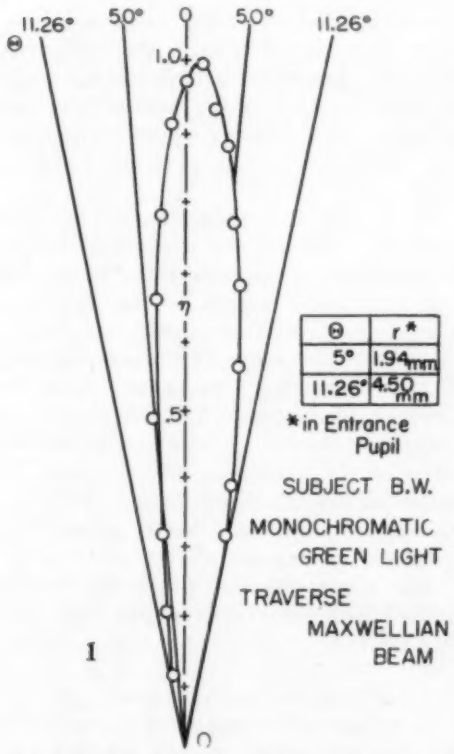


Fig. 1. Relative luminous efficiency as a function of retinal angle of incidence. This is a typical normal Stiles-Crawford function. Equivalent entrance pupil radii are presented.

stray light or veiling glare exists in the human eye for the angles measured than shows up in psychophysical measures of glare functions. It was their hypothesis that because of the highly directional nature of the sensitivity of the eye, due to the Stiles-Crawford effect, this stray light was largely not absorbed by the cones. In other words, stray light has less effect on vision than might be anticipated. Hence, if that which were oriented is totally non-oriented, i.e., shows no differential directional sensitivity, one would expect up to one log unit more stray light absorption for any given angle of retinal incidence.

The effect of a glare source is largely to reduce contrast, increase light adaptation, and if sufficiently intense, to cause discomfort. These

effects generally tend to reduce acuity and sensitivity. The amount and effect of glare is further dependent upon the configuration, size and luminance of both the glare source and the background. In addition the adaptive and refractive states of the observer have an effect. Thus, if one varies the above parameters one would expect a variation in the amount of stray light absorbed by receptors which are differently oriented.

One may ask, how may receptor tilt occur and is it permanent? Certainly since the outer limbs of the receptors are not attached, group tilt or general non-alignment may arise either as the result of a blow to the eye or due to excessive pressure on the eye (for example, that which may be exerted at birth) or possibly, tilt may be related to gravitational stress forces. Interestingly a paper was recently published by White and Jarve[14] showing a progressive temporary decrease in acuity in the presence of increasing "G" forces, with maintenance of normal blood supply to the eye. It may be that excessive centrifugal or centripetal force on the unattached outer segments of the receptors was responsible for this loss in acuity. Another possibility is the lateral pull on the retina by the ciliary body during accomodation. The effect in this instance for any given group of receptors would depend largely on whether the pull is uniform in all directions. Perhaps this may be related to Ronchi's[16] variation in relative luminous efficiency findings when drugs are employed.

EXPERIMENTAL

The author had available (unfortunately only for a very brief period of time) a trained subject manifesting amblyopia in one eye.* Most important, data are available on this subject's basic visual functions.[15] Further, since the visual acuity in the amblyopic eye was 20/40—, a major fixation error is not possible.

The instrument employed to test the subject has been described at length elsewhere[12] and is shown in Figure 2. In brief, a source of light, S1, is divided into two paths by a beam splitter. Punctate images of aperatures A3 and A2 are focused in the plane of the entrance pupil of the eye. The image of A2 is traversed across the entrance pupil of the eye by rotating mirror M2, while the image of A3 remains centered in the pupil. Apertures A4 and A1 are conjugate with the retina and form the bipartite test field.

A source, S2, provides illumination for a secondary system which is used as a constant monitor on subject position and in addition aids in subject fixation. In essence a shadow image of aperture A5 is projected

*The author wishes to acknowledge the kind cooperation of Dr. T. P. Grosvenor.

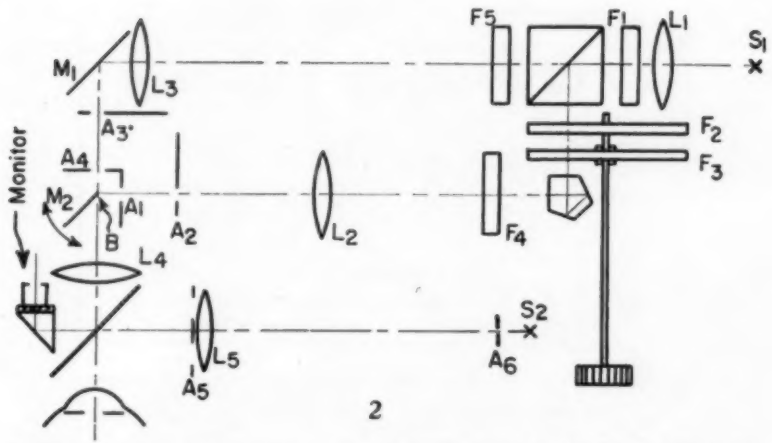
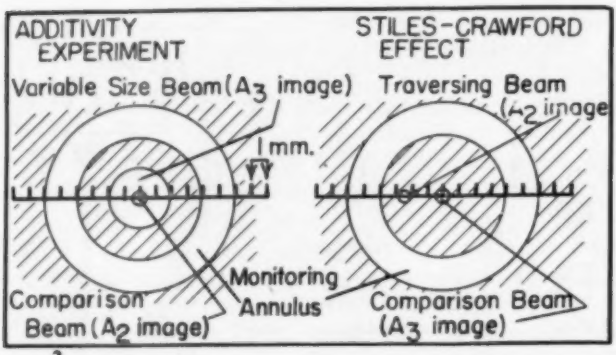


Fig. 2. Direct comparison apparatus used in measures of the Stiles-Crawford effect.

into the eye. This aperture is in the form of an annulus. The outer border is larger than the physical size of the entrance pupil of the eye. Thus the pupil of the eye in effect forms the outer border of the annulus pattern. Centration is assured by positioning the pupil border in such a fashion that it is concentric with the inner border of the annular field. The exact stimulus pattern in the pupil is continuously under observation and control by means of a monitoring device. Illustrations of the patterns seen through the monitor are seen in Figure 3. The additivity experiment pattern is not applicable in this study. A reticle pattern of a millimeter scale allows exact positioning of the beams in the entrance pupil of the eye. Centration is further checked by means of determining the point of cut-off of the traversing beam and the nature of this cut-off. Figure 4 shows the stimulus pattern as seen by the subject. The appearance of the pattern when centered and not centered is shown.

The size of the centered beam in the entrance pupil was 0.60 mm. and the size of the traversing beam was 0.86 mm. The bipartite field subtended an angle of 1°36′. The luminance level of the comparison field was maintained at 4.35 millilamberts. Monochromatic light having a wavelength of 552 mμ was employed.

The subject's eye was dilated with paradrene hydrobromide, 1% ophthalmic solution. This drug produces mydriasis with only slight cycloplegia. Experimentation was not undertaken until dilation was complete. One drop was administered every fifteen minutes during each



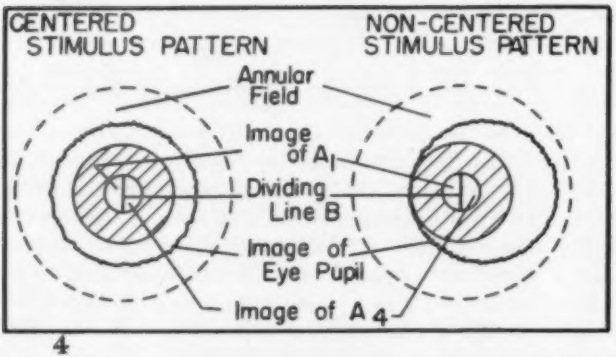


Fig. 3. Patterns seen objectively through the monitoring device for additivity and Stiles-Crawford effect experiments.
Fig. 4. Subjective pattern seen for experiments using the direct comparison apparatus, centered and non-centered.

experimental session in order to maintain constancy of dilation. This was intended to prevent the variation of the Stiles-Crawford effect with time after instillation of a mydriatic as was reported by Ronchi.[16]

After carefully positioning the subject who was held firmly in place throughout a test session by means of a headrest and bite bar, a period of time was allowed for cone adaptation prior to testing. A traverse started in the middle of the entrance pupil. After suitable practice ten readings were taken at each half millimeter setting, either traversing left or right until the pupil border was reached. At the completion of each traverse the variable position beam was again centered in the entrance pupil of the eye. A second traverse in the opposite direction was made. At a second experimental session the ordering of traverse

was reversed. Settings were made by matching the central regions of the two halves of the bipartite field by means of adjusting a neutral density wedge which varied the luminance of the test field.

Thus the instrument provides both central and peripheral fixation for the subject and a means of continuously monitoring his position.

The case history of the subject T. G., age 33, quoted directly from his dissertation[15] is as follows:

"Uncorrected distance acuity: O.D. 20/400
O.S. 20/200

"Refractive error: O.D. —4.50 D. sph. ⌒ —3.75 D. cyl. X 175
O.S. —3.75 D. sph. ⌒ —3.25 D. cyl. X 169

"Corrected distance acuity: O.D. 20/40 (—)
O.S. 20/20

"Status of binocular vision: 18 prism diopters of exophoria, and 9 prism diopters of left hyperphoria, at both distance and near. Fusion and 80% stereopsis obtainable without the use of prisms, although 6 prism diopters base-in and 4 prism diopters vertical prism are included in the subject's lens prescription.

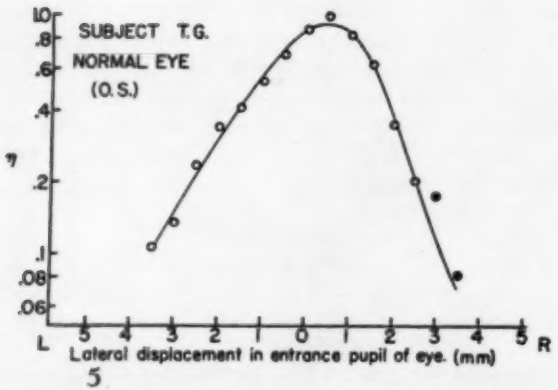
"Fixation: A plot of the blind spots showed them to be in corresponding positions for the two eyes, indicating central fixation for the amblyopic eye. The after-image transfer test also indicated central fixation for the amblyopic eye.

"History: The subject has a history of intermittent right exotropia at the age of six, the onset of which was subsequent to scarlet fever. The exotropia was accompanied by diplopia, but this was relieved when minus lenses were prescribed.

"The amblyopia was evident at the first refraction, and the corrected acuity of the amblyopic eye has been fairly constant since that time." (The onset of the amblyopia, therefore, may or may not have been associated with the squint and vice versa.)

Fry[17] has measured the luminoscity curves for both eyes of the subject and found them to be within normal limits.

The subject's refractive correction was placed in trial frame rings, and was centered in front of the eye under test. A total of four test sessions were conducted, two for each eye. The test results are shown in Figures 5 and 6. Each open circle is the mean of twenty readings. While it is ordinarily the habit of this investigator to discard incomplete data sets, he felt the importance of these data warranted their inclusion. The blackened circles represent data obtained at only one test session and are therefore the means of ten readings rather than twenty. Discontinuance of a test session may be caused by a subject



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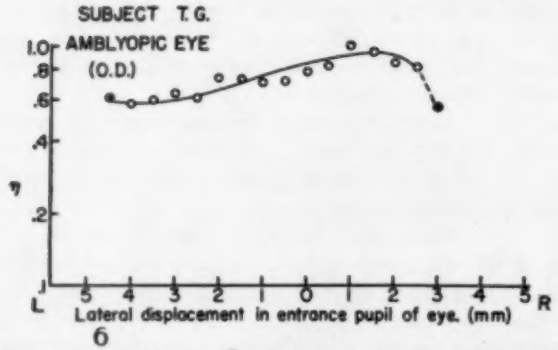

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Fig. 5. Normal eye of subject T. G.: Relative luminous efficiency is plotted as a function of the position of a horizontal traversing beam in the entrance pupil of the eye. Black circles represent means of ten rather than twenty data points.
Fig. 6. Amblyopic eye of subject T. G.: Relative luminous efficiency is plotted as a function of the position of a horizontal traversing beam in the entrance pupil of the eye. Black circles represent means of ten rather than twenty data points.

shifting position or by the overlapping or separation of the semi-circular test areas of the bipartite field (due to the subject getting out of alignment or to aberrations of the eye or to aberrations or prismatic action of the correcting lens). The subject indicated that the stimuli were colored throughout the test procedures therefore indicating cone response.

Let us now consider these results. Figure 5 shows the curve of relative luminous efficiency for the subject's normal eye for a horizontal traverse. This may be considered a relatively normal Stiles-

Crawford pattern, although a slight tilt is manifest.

If anything the sensitivity tends to fall off more rapidly than normal as most test results tend to be somewhat flatter at the peak. This is believed to be related to the effectivity of the negative lens placed before the subject's eye (for which the data have not been corrected).

Looking now at Figure 6 this pattern taken on the subject's amblyopic eye cannot be considered normal. If any or all theories of the Stiles-Crawford effect are valid the receptors in this eye are in poor alignment. It will be noted that the entire distribution varies approximately one third log unit. Flamant and Stiles[6] previously reported a subject (apparently with normal vision) with a distribution (measured 5° parafoveally) which was quite decentered. However, this particular distribution although tilted varied over an entire log unit and hence the receptors of that subject cannot be considered as being as greatly out of alignment as those of the subject described here. Thus, it is the hypothesis of this author that the amblyopia of the subject T. G. is due to either gross non-alignment or tilt of central retinal receptors.

As part of Grosvenor's dissertation an attempt was made to compare just noticeable difference luminance tresholds under a variety of experimental conditions for his normal and amblyopic eyes. He summarizes his general results in the following statement:

"In comparing the data for the normal and amblyopic eyes, probably the most obvious fact is that, under identical conditions of background luminance, slit width, and duration of exposure, the contrast threshold for the amblyopic eye is somewhat higher than that for the normal eye, in almost all cases." However, he does note that the ratio of sensitivities between the two eyes seems to vary somewhat with luminance level.

Thus, one may say on the basis of the findings on the subject that the general premises of the theory are supported. Unfortunately time did not allow more extensive testing.

Assuming the validity of the conclusions drawn above one must consider the implications. First, a certain per cent of amblyopia may be ascribed to the orientation of retinal receptors. This would also apply to patients with binocular vision whose acuity does not meet accepted standards. Further, in the light of present knowledge, it would mean that these cases probably cannot be trained. Certainly the next step is to obtain more information and additional subjects. Then it will be important to determine the proportion of amblyopes whose

reduced vision is associated with poor receptor alignment and subsequently it will be necessary to find simple valid screening tests which are applicable clinically. In addition, from the point of view of the investigator interested in the Stiles-Crawford effect and the nature of the receptor process these cases may provide considerable information.

CONCLUSIONS

A theory has been presented which relates orientation of retinal receptors to amblyopia. In terms of all theoretical treatments of the Stiles-Crawford effect these measures of relative luminous efficiency are dependent upon retinal orientation.

A subject has been tested who manifests a relatively normal Stiles-Crawford pattern in his normal eye and the most distorted pattern yet recorded in the literature in his amblyopic eye. Other experimental data available on this subject support, in general, the hypotheses put forward in this paper. Further work is now needed to determine the nature of and the incidence of retinal receptor tilt as a cause of amblyopia and to find a simple but valid clinical means of testing the orientation of the receptors.

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MATERIALS REVIEW

AMERICAN OPTICAL LINDER OCCLUDERS

The need for improved types of occluders has long been recognized by members of the ophthalmic professions. Now, American Optical Company has available two new occluders, the Linder Cup Occluder and the Linder Patch Occluder. These were designed by the writer.

The Linder Cup Occluder is precision molded of a soft flesh-toned plastic. Molded into the front portion of the occluder is a metal insert which provides rigidity, aiding the forming of the device to both facial contour and frame. As the occluder is of one-piece molded construction, the cup is of the same soft material. This cup can easily be trimmed to assure complete occlusion and allow fitting with maximum comfort. The inside surface of the cup is black, which prevents the reflection of any extraneous light.

The metal insert which is molded in the front portion of the occluder has three tabs. These tabs are for the purpose of attaching the occluder to the eyewire of the frame. The tabs can be bent and easily cut to length assuring positive attachment to eyewires of varied thicknesses. The design of the tabs will allow removal and reattachment of the occluder if necessary. Three sizes are available. They are 38 mm., 42 mm. and 46 mm., left or right. This range of sizes fulfills the many fitting demands.

Another advantage of the occluder is the fact that it can be readily used for pinhole occlusion. For accurate location of this pinhole, a paper grid is packaged with each occluder which is used in conjunction with the crosslines molded on the front surface. The patch occluder is designed for cases where an eyecup is not desired. It is of the same basic construction and material with the same range of sizes as the cup type.

EDWARD LINDER, JR.

STREET-LINDER, INC.

AN EVALUATION OF STEREOPSIS TESTS*

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DEFINITION

Stereopsis is the term applied to tri-dimensionality or the appreciation of depth. It is derived from two Greek words: (1) stereos, which means solid or firm, and (2) opsis, which means appearance or sight.

According to Scobee: "If a patient can accurately locate objects in his environment with respect to their distinction both from himself and from each other, and if this discrimination is present to a relatively high degree, he is said to have third degree fusion or depth perception." Hence, the highest degree of single binocular vision is stereopsis which is the result of mental blending of two slightly dissimilar retinal images from disparate points in space.

DEVELOPMENT OF STEREOPSIS

Gesell and others, writing on the subject of child development, have stated that a child is not born with the visual sensations of third dimension. As far as we know, the infant is visually conscious of only flat surfaces in the early months of life. The newborn infant comes into a world of light with a pair of eyes that are not sufficiently developed to cope with the visual impressions about him. Although various anatomical structures of the eyes including the appendages are well formed before birth, the physiological responses must be further developed through proper usage. Infant's eyes are visually sensitive only to light, for the macular area has not been developed to any great extent and the optic nerve fibres are not as yet myelinated.

Chavasse, in his study of development of vision, said that "a child is not born with 6/6 vision. This 6/6 vision is a conditioned reflex which develops with appropriate stimulation and reinforcement." In line with these observations, Scobee declared that the normal child possesses approximately 20/2000 vision at four months, 20/1000 at six months' age level, and 20/200 at nine months, 20/50 at one year,

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†Optometrist. Member of faculty. Fellow, American Academy of Optometry.

20/30 at three years, 20/25 at four years, and finally reaches 20/20 at five years.

During the first weeks of post-natal life, as central vision is being established, there is a lack of binocular pattern of vision. At this point seeing is strictly monocular. The two eyes of the infant roam aimlessly in space as each eye alternately fixates various objects within the visual environment. As the fovea develops in sensitivity, the infant learns to fixate the visual impressions that he receives in his brain through the co-ordinated act of the use of his hands and eyes. Thus, the infantile eyes learn to follow objects in the fields of vision by co-ordinating actions of the extra-ocular muscles. Normally, the child learns to fixate objects by making the compensatory motions of dextra-version (both eyes to the right), laevo-version (both eyes to the left), supra-version (both eyes upwards) and infra-version (both eyes downwards). These movements result from the yoked muscle actions of conjugate sets of muscles and later become the well developed versions in the adult.

At this point in the development of the human visual apparatus, there enters the first conflict in the visual centers of the child's brain—*diplopia*. Since the first acts of binocular co-ordination are somewhat crude and inaccurate, occasionally the infant experiences the sensation of double vision. This visual phenomenon occurs whenever images from external objects fall on non-corresponding retinal areas. As a result of this visual experience, the child soon learns that he must co-ordinate his eyes in such a manner that the two foveas will receive similar images simultaneously. Here, perhaps, for the first time does the child find the true meaning of single binocular vision—*fusion*. Normally, this fusional desire develops through further experience and reaches its peak during the eighth year of life. Thus, the highest degree of single binocular perception or stereopsis is achieved.

How then do we perceive the unusual phenomenon of third dimension? For clarification, a short review of basic concepts of physiological optics will bear repeating at this time. For each corresponding retinal point in either eye there is an external point of projection in outer space. The composite of all of these external points make up what is known as the horopter. In other words, the horopter is that imaginary arc in space which is formed by the external projections of all corresponding retinal points. Points on the horopter have no stereoscopic value since they are equidistant from the observer. Furthermore, any point that is in front or behind the horopter must necessarily appear double due to physiological diplopia. Stereopsis is apparent when the points lie slightly in front or slightly behind the horopter *but not far enough in front* or

behind to be seen double. This was the hypothesis first propounded by Panum—that disparate points which are either in front or behind the horopter (Panum's area) can be fused by the brain so as to give the visual sensation of solidity or third dimension.

FACTORS THAT GOVERN APPRECIATION OF DEPTH

In consideration of factors that aid the individual to correctly judge objects in space, we must bear in mind that there are: (1) *monocular clues* and (2) *binocular clues* which are of importance in vision. The former group includes:

a. The apparent size of the object in space.
b. The apparent shape of the object.
c. The effect of light and shadows on the object.
d. The effect of parallax on viewing the object.
e. The effect of aerial perspective on viewing the object.
f. The amount of accommodation in use.

The foregoing contributory factors are usually the clues that help the one-eyed individual to judge depth. It is generally assumed that monocular clues for space perception are learned by experience and practice. Therefore, the patient who loses an eye in early childhood learns to depend on his monocular clues for his visual orientation throughout life. A normal two-eyed individual who suddenly loses the sight of one eye must re-learn to judge distances through the use of monocular clues.

But the individual who has the use of two eyes with a well developed fusional amplitude has a distinct advantage over the one-eyed individual. In addition to the monocular clues, he can utilize binocular clues to further enhance his judgment of space. The binocular clues are:

a. Binocular parallax.
b. Physiologic diplopia.
c. Convergence.
d. Retinal rivalry.

IMPORTANCE OF TESTING THE DEGREE OF STEREOPSIS

As an adjunct to refractive techniques, it is professionally wise to ascertain the degree of binocular development the patient possesses, for the following reasons:

To determine the prognosis of a tentative orthoptic case for your own management of a heterophoria or heterotropia or for the advisability of referring the case to another practitioner.

To test applicants for various dangerous occupations, according to Kuhn, in "Eyes in Industry," all of the following occupations should

be tested for stereoscopic ability: crane operators, moving machine operators, electric truck and tractor drivers, feeding machine operators, and structure and maintenance workers.

To test applicant's depth perception for driver's licenses since stereopsis is already a visual requirement in several states and in due time, may become a pre-requisite for granting of automobile licenses. Lack of stereopsis may be a factor in the high rate of accidents on our highways.

To test patients who may inquire as to their stereoscopic ability with respect to their particular hobby or avocation. Many patients are interested in stereo-photography, art, and three dimensional movies. We may also include in this category the sports enthusiasts who enjoy bowling, tennis, golf, or baseball. In fact, judgment of stereopsis is very important in all activities where hand and eye coordination is a combined act.

To test applicants for the various branches of the Armed Forces.

METHODS OF PRODUCING STEREOSCOPIC EFFECTS

During the long history of the science of optics, there have been numerous methods of producing the unusual effect of third dimension or stereopsis. An early method of producing the effect of depth was the chromatic anaglyph. The theory behind the creation of the anaglyph was that the stereoscopic impulse in the brain depends upon the simultaneous stimulation of two retinas by different stimuli. Using knowledge of the artist that complimentary colors when mixed, produce the sensation of white, the originator of the first chromatic anaglyph utilized red and green as the two colors. The first stereo picture was a composite print of a red picture with a green picture of the same scene printed directly above it. These two complimentary colored pictures were viewed through a pair of red and green spectacles thus creating the sensation of depth. However, due to the fact that many individuals found it difficult to blend these two dissimilarly colored pictures perfectly (retinal rivalry) without ocular malaise, this method of producing stereopsis never quite realized the fullest popularity for the amateur or professional. Today, we in optometry still utilize the possibilities of the chromatic anaglyph in the specialty of orthoptics in the Brock red and green rings for stereo-motivator apparatus, visual training workbooks in 3-D, and various other training procedures. Though the anaglyph process of stereopsis may have merit as a training technique, nevertheless the writer does not consider this method accurate as a testing procedure.

The most popular method of producing stereoscopic pictures came with the introduction of the stereogram and the stereograph. With

the invention of the stereoscope by Wheatstone and its subsequent development by Oliver Wendell Holmes, the stereograph became a source of infinite pleasure in the home during the late eighties. It was Holmes, scientist, artist, and seer, who foresaw the future of stereoscopy as a visual medium for generations to come.

To many practitioners, the two terms "stereogram" and "stereograph" are synonymous or interchangeable. The writer feels that there is a basic difference between these two types of stereoscopic plates. I consider the stereogram to be a print composed of geometric patterns so drawn as to stimulate the awareness of third dimension by utilizing perspective, binocular parallax, and the convergence-divergence relationship. The best example of this method of stereoscopy is to be found in the original Wells' selection of stereoscopic charts (14th edition, American Optical Company) which were introduced in 1918. In this series of charts, the E 1-10 slides are devoted to the cultivation of stereopsis by geometric patterns and the J 1-2 slides by binocular parallax. There are, of course, other examples of the stereogram technique which are used quite extensively in orthoptic training these being the Dvorine animated fusion training charts (Group F), Renshaw split stereograms for the stereo disparator, and Pine fusion alphabet series. This method of producing stereopsis lends itself very well to the practitioner as an office and home training technique.

By comparison, a stereograph is a photograph which produces the effect of third dimension if viewed by the observer in a stereoscope. The original stereograph was made popular by the Keystone View Company in the late eighties as a form of parlor entertainment in the home. Today, the stereograph is utilized daily in the modern optometric practice as a means of perfecting various visual skills. A stereograph picture is taken with a stereo camera which has a dual aperture arrangement equivalent to the average distance between a pair of human eyes. Thus, two negatives are made of the identical scene but from slightly separate points of view. The stereograph must then be viewed through a stereoscope with the end result that the dual components are fused by the observer into a single image giving the sensation of third dimension. Today, with the introduction of color photography and the production of more economical stereo cameras there has been a revival of interest in stereoscopy. It is also quite possible that we may see in the early future a vastly improved three dimensional cinema and perhaps three dimensional television. In orthoptic practice, today, the stereograph has been the backbone of all of the Keystone visual training equipment and training slides.

The most recent innovation in methods of producing stereopsis came with World War II. This is the process known as the vectograph or polarization anaglyph. Though the idea of utilizing polarized light as a medium of producing third dimension was known in optical science a century ago, it took the invention of an inexpensive material called polaroid by Land and Mahler to give this technique its greatest boom. The vectograph is a fundamentally new kind of pictorial representation which makes it possible to produce a three-dimensional picture in the form of a single print. Vectographs may be prepared in several different forms, corresponding to the photograph: reflection prints, transparencies, lantern slides, and even film for projection on a screen for large audiences. The vectograph process of stereoscopy was widely used as an aid in aerial photography by the armed forces during the past war. The same basic idea has been adapted for visual training purposes by Bausch & Lomb Optical Company with the introduction of its ortho fusor series.

Vectographs are made from normal stereo negatives, but instead of being printed in complementary dyes, they are printed by the dye transfer process in a dye which crystallizes in dichroic form. By printing the image on two sides of an optically-active transparent base, the two images are polarized at 90 degrees to each other. Thus, the examination of such a dually superimposed print through a pair of polaroid 3-D spectacles reveals an appreciation of third dimension. At the present time, the production of color vectographs for still projection and movie film is being awaited by the public as well as by optometrists.

INVENTORY OF STEREOPSIS TESTING APPARATUS

In discussing the individual tests for the measurement of stereopsis, one steps on dangerous ground. Many claims have been made by manufacturers of ophthalmic equipment as to the ease with which the degree of stereopsis can be measured with their instruments and slides. Various claims have also been mentioned as to the measurement of the degree of stereopsis, but as yet, no standards have been set up by optometry for this. It then remains for each examiner, to state *only* the results of the individual test on the particular instrument or slide that was used for the test.

However, it is the writer's opinion that it is wise to investigate all available tests for the measurement of stereopsis, for each method has its merits and its faults. Only by personal evaluation can the optometrist decide which test should be used in his routine examination.

During my review of methods of producing stereopsis, the writer has mentioned the *chromatic anaglyph*, the *stereogram*, the *stereograph*,

and finally the *vectograph*. These prints or plates only measure qualitatively the degree of stereopsis; that is, has the patient poor appreciation of depth or has he a fair awareness of third dimension or has he a high degree of tridimensionality. In order that the optometrist may be able to determine the quantitative degree of stereopsis, he must have at his command a battery of tests which can not only determine the appreciation of third dimension but also measure the amount of stereopsis.

In testing a patient's stereoscopic ability, one may use as simple a test as a hand chart, a hand stereoscope, or one of the more elaborate ophthalmic instruments. Each type of testing equipment will now be reviewed.

1. *Hand chart test.* Wirt stereo-test. Three Dimension Company. This test is based on the vectograph principle of producing stereopsis and can be employed as a quick test for measurement of depth perception. Since the size of the test chart is equivalent to that of a near point reading chart, it may be held by the patient at arm's length or attached to the reading rod of a phoropter. According to the manufacturer of this chart, it is possible to measure a variation of 5% - 105% stereopsis (Shepard percentage). A pair of 3-D viewers is supplied with the test.

2. *Stereoscope:* Brewster model.
   a. Wells charts (series E 1 - 10)—stereograms.
   b. Bausch & Lomb stereo card (Poser)—drawings.
   c. D. C. Health Co. stereo card (geometric design).
   d. Keystone DB 6 stereopsis card (figures).
   e. Keystone stereographs (0 33 and 0 34)—photographs.

3. *Telebinocular—Ortho trainer—Omni trainer:*
   a. Qualitative measurements—cards in section 2.
   b. Keystone DC series (aviators)—DC 31 - 53.
      Quantitative measurement unit 1%-110% stereopsis based on variation of seconds or arc.

4. *Bausch & Lomb ortho fusor series.* This series of visual training transparencies is based on the vectograph principle. Though they are intended primarily for the management of binocular imbalances, they can be utilized as tests for the qualitative measurement of appreciation of stereopsis.

5. *Rotoscope.* Slides 15-26. The testing and training slides for use with the rotoscope can be utilized as a quick measurement of the appreciation of sterescopic and pseudoscopic vision. The principle upon which these slides is based is the geometric design or stereogram. Plac-

ing the slides in reverse in the instrument will produce the opposite effect of stereopsis. This particular effect has its advantages in testing and training the patient.

6. *American Optical Verhoeff stereoptor.* This instrument is a hand operated device which can be used principally for the quantitative testing of acuity and dependability of binocular stereopsis. The instrument is about the size of a small book and is made of black plastic. It has an illuminated window in which eight black targets are presented successively against a white background. The examiner manipulates the changes in the position of the rods and exposes the instrument to the patient at the distance of one meter. According to Verhoeff, the usual misleading size differences of the retinal images of the target elements make binocular parallax the only correct evidence of relative depth perception.

7. *Howard-Dolman test.* This instrument is one used by the U. S. armed forces and the civil aeronautics board for testing applicants for aviator's license. It is a box-like apparatus, one foot high, one foot wide and three feet long, which has two rods set 60 ca. apart laterally at the "zero position" of a measuring scale. The subject is instructed to pull on the attached cords so as to correctly align the two vertical rods. This test is taken at the conventional twenty foot distance, which is the main objection to its use in the average office of limited space.

8. *Keystone multi-stereo tests.* This new series of stereopsis tests, manufactured by the Keystone View Company, consists of 18 stereographs which include three testing cards and 15 training cards. According to their research department, these tests have set a definitely higher standard for critical measurement or stereopsis. This complete unit represents the first set of stereopsis tests that is calibrated from 1300 to 10 second degrees of an arc. Though the test is vaguely similar to the Howard-Dolman test, all hand and eye coordination has been completely eliminated as a factor of judgment of stereopsis. All extraneous clues have been eliminated so that nothing but distance perception is tested.

Testing card A (instruction only): 3%-25% stereopsis.
Testing card S 1: 45%-70% stereopsis.
Testing card S 2: 75%-100% stereopsis.
Training cards 1-15: from 45% to 110% stereopsis.

9. *A. O. Sight Screener.* Red series (distance)—test 5. Black series (near)—test 5. Included in the complete battery of visual screening tests, there is a chart for measurement of depth perception. Since

this test is only a quick method of determining the appreciation of depth, the sight screener measures grossly the stereoscopic ability at distance and near points. The percentages are based on the Shepard-Fry scale from the minimum of 45% to a maximum of 105% with the stereoscopic effect produced by the vectograph principle. Evaluation: quick test applicable only for large group testing needs such as in industry or school systems.

10. *Bausch & Lomb ortho rater.* Test F-6. The B & L ortho rater, a visual screening instrument for group testing in industry, schools, and motor vehicle licensing, has a slide for the measurement of the appreciation of depth. Included with this test is a depth demonstrator which is used by the examiner to demonstrate to the subject what is meant by stereopsis. This test was meant only for screening purposes and is qualitative in measurement of stereopsis.

11. *Keystone visual survey telebinocular.* Test No. 5. The Keystone occupational visual service includes a test chart for measurement of depth perception for far point testing only. It is an abbreviated version of the familiar DB 6 D chart used by optometrists for testing visual skills. Instead of 12 rows on the DB 6 D card, the test in the occupational visual service has only six rows for a rapid test of the appreciation of stereopsis. This test is only applicable as a screening test for large groups.

CONCLUSIONS

Since it is established in the field of visual science that stereopsis represents the height of development of binocularity in the evolution of man, it behooves the profession of optometry to investigate and establish a series of acceptable standards for the measurement of stereoscopic acuity.

With the ever increasing rate of speed of production in industry, the increase in road traffic on the modern highways, and the increase in leisure time available to the future generations for avocational pursuits, it seems to be imperative that a measurement of stereoscopic ability be made an integral part of the modern optometric examination.

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TRANSACTIONS OF THE AMERICAN ACADEMY OF OPTOMETRY

A department devoted to announcements, reports, appointments, organization data, news, professional problems and ideals, as these relate to the Academy.

SECTION ON PATHOLOGY

The Pathology Section occupies a somewhat unique place within the organization of the Academy. This uniqueness is imparted by the fact that the treatment of pathological conditions falls outside of the domain of optometry. This has led to the fact, with certain notable exceptions, that optometrists have contributed little to the literature in this area.

However, among members, interest has always been high in all phases of detection, recognition and, to a considerable extent, treatment of pathological conditions. It would seem therefore that the Pathology Section can best serve the profession in the following ways: (1) To keep the optometrist up to date on all recent developments and techniques in pathology as applied to optometric practice. (2) To provide a means for review of basic principles of ocular and general pathology. (3) To be the responsible optometric agency for the testing of new equipment and the validation of techniques in the detection and recognition of pathological conditions. (4) To encourage and support, in any feasible manner, increased undergraduate training in general and ocular pathology. (5) To encourage optometric research in pathology, with particular emphasis upon research into means and methods of detecting, and recognizing ocular pathological conditions without application of drugs. Included also in this category would be the registering of unusual case records.

JAY M. ENOCH, O.D., PH.D.

CHAIRMAN,
SECTION ON PATHOLOGY

STUDIES OF FIXATION DISPARITY— HISTORICAL REVIEW*

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The fixation of an individual attempting to fixate a target is not exact. The eye has been demonstrated to be in constant oscillatory motion called physiological nystagmus in both monocular and binocular vision. However, we do not perceive targets at which we are looking as oscillating back and forth. The visual mechanism has the ability to integrate sensations resulting from the oscillatory stimulation of several points in the retina, and thus also of several points of area 17 of the visual cortex. The resultant percept of the object being fixated is that it is single, in one direction only, and perfectly stationary. In binocular vision, this directional integrative ability is the basis for the phenomena of Panum's fusional areas and of binocular stereopsis.

This ability of the visual mechanism to integrate, into a single percept, neural activity arriving at separate points in area 17, provided they are not separated too greatly, also permits the phenomenon of fixation disparity. Fixation disparity is a minute strabismus existing in normal single binocular vision. The foveal lines of fixation do not intersect exactly at the object upon which exact fixation is being attempted.

Panum (1858) was probably the first to demonstrate that a percept of singleness will result in binocular vision even if the optical images of an object fall on non-corresponding parts of the two retinas, provided that the disparity from stimulation of corresponding points is not too great.[3] The angular disparity which can exist and still allow

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[3]Corresponding points are points in the two retinas which, when separately stimulated, give rise to the same directional percept. Ogle (1950) referred to these directions as being "subjective *primary* visual directions: primary in the sense that the *visual directions are those associated with retinal elements were the images from the two eyes not fused.*"

singleness has been called Panum's fusional area. The size of these fusional areas varies from individual to individual and with the area of the retina being tested. The best estimates of the size of Panum's fusional area near the center of the fovea vary from 6 to 15 minutes of arc (Volkmann 1859, Ogle 1932, Brecher 1942). Much higher values, up to 30 or 40 minutes of arc, are found only 10 or 15 degrees away from the foveas.

The amount of fixation disparity which can occur in any stimulus situation is limited by the size of the smallest Panum's fusional area being stimulated binocularly. When the inexactness of motor fusion exceeds the radius of Panum's fusional area, diplopia will occur. While the existence of Panum's fusional areas allows fixation disparity to occur, only under conditions of extreme stress to the motor fusional mechanism does the magnitude of fixation disparity approach the size of Panum's fusional areas.

EARLY EXPERIMENTS

That attempted bifoveal fixation is not necessarily exact was probably first demonstrated by Lau (1921) during a series of experiments on the horopter employing a haploscope. He found it was necessary to misalign two vertical lines oriented one above the other, one seen by the left eye and the other seen by the right eye, before they were perceptually aligned. As Lau's targets both had a long central line which acted as a stimulus to motor and sensory fusion, Lau concluded that this physical misalignment of perceptually aligned monocular lines demonstrated inexact bifoveal fixation of the binocular lines of the targets. Lau found that the physical misalignment necessary for perceptual alignment increased as he forced convergence.

Lewin and Sakuma (1924) placed playing cards on the arms of a haploscope such that the outer diamonds of a five-of-diamonds card were fused with the four diamonds of a four-of-diamonds card. The central diamond of the five-of-diamonds card was found to be perceptually displaced laterally relative to the fused outer four diamonds. This displacement varied with the convergence demand. This experiment can be repeated by anyone with a deck of cards and a reasonable facility at chiastopic fusion. By forcing convergence, a marked displacement of the central diamond will often be seen.

The first English language report concerning the inexactness of binocular fixation was that of Ames and Gliddon in 1928. They made an extensive study of this phenomenon, which they termed "retinal slip," and its relation to heterophoria and motor fusion movement of convergence, divergence and cyclovergence. They used a haploscope to

obtain two targets, one presented to each eye, which had in part identical patterns and in part dissimilar monocular check marks. The identical parts fused and appeared single while the dissimilar check marks appeared, under certain conditions, to be displaced laterally relative to the fused pattern. They concluded that the displacement of the monocular check marks indicated a failure of exact fixation. The check marks were perceived in the true primary direction of the stimulated areas of the retinas, while the fused binocular contours were in some way perceptually displaced so that single vision might occur.

Ames and Gliddon found that the magnitude of retinal slip varied with different individuals, with the amount of vergence movement necessary to obtain fusion, and with the angular separation between the monocular check marks and the fused parts of the targets. They found that under conditions of extreme stress to the motor fusion function that the amount of slip reached about one degree of arc. Using 51 observers, they found a close correlation between the direction of the heterophoria exhibited by the observer with disassociation of the eyes and the direction of the retinal slip. They also found good agreement between the heterophoria and the vergence necessary to bring retinal slip to zero.

By using plus and minus lenses they varied accommodation and found a change in retinal slip in the convergent direction with increased accommodation and in the divergent direction with decreased accommodation. These changes occurred so consistently that they concluded that relative accommodation, a change in accommodation which does not affect convergence, could not exist. Although their apparatus did not permit quantitative measurements of the amount of retinal slip, they concluded that the amount of slip was not appreciably different whether the fusion pattern was central or peripheral in the visual field.

Ames, Gliddon, and Ogle (1932) in a paper on the use of the direct comparison eikonometer pointed out that the occurrence of retinal slip can be a factor in the use of this instrument. Many patients report that the monocularly seen check marks are displaced symmetrically, indicating an inexactness of fixation in addition to a possible difference in the size of the ocular images of the two eyes.

FIXATION DISPARITY AND HETEROPHORIA

The outstanding contribution to the understanding of fixation disparity and its role in binocular vision was that of Ogle and his co-workers (Ogle, Mussey, and Prangen 1949; Ogle 1950; Ogle and Prangen 1951; Ogle and Prangen 1953). In a series of experiments carried out at the Dartmouth Eye Institute and at the Mayo Clinic, Ogle and his co-workers developed the concept that the inexactness of

binocular fixation is an indication of the stress on the visual fusion mechanism. They were the first to use the term "fixation disparity," which they applied to inexact binocular fixation irrespective of whether the binocular fusion clues were foveal or peripheral in the visual field. In their use of the term, "fixation disparity" thus had the identical meaning of the earlier term "retinal slip" of Ames and Gliddon.[4]

Ogle and his co-workers confirmed Ames and Gliddon's observation that the heterophoria and the prism vergence necessary to reduce to zero peripheral fusion fixation disparity were nearly always in the same direction and usually quantitatively similar. By using apparatus which allowed as quantitative determination of fixation disparity, they found that a moderately high positive correlation existed between fixation disparity and heterophoria. However, they reported a number of individuals who did not have a close agreement between these two functions. Several subjects were even found who had fixation disparities and heterophorias of opposite character.

Tubis (1954) on 19 subjects compared the hyperphoria exhibited under conditions of dissociation of the eyes by horizontal prism and the prism vergence necessary to reduce to zero vertical fixation disparity. He found marked agreement between the two functions, with a coefficient of correlation of +0.90. However, the amount of hyperphoria indicated by the dissociation test was generally about 20 to 25 per cent higher than the prism vergence result.

EFFECT OF FORCED VERGENCE

Using a standard test situation in which the binocular fusion clues were no closer than 0.75 degrees to the center of the visual field, Ogle and his co-workers were able to classify subjects into four general types as to the changes in peripheral fusion fixation disparity that occurred with forced vergence. The two main types, both composed of subjects with adequate binocular vision, were characterized by whether or not they showed a continuous change in fixation disparity as convergence or divergence were forced by prisms. The largest group of Ogle's subjects showed changes in the amount of fixation disparity over the entire vergence range.

[4]Objection has been raised to the use of the term fixation disparity to describe the inexact orientation of the eyes in a situation in which there is no binocular foveal fusion target as being semantically improper because the term fixation means to observe foveally. Strict consideration would limit the term fixation disparity to inexact binocular fixation of a foveal fusion target. The author prefers to follow the precedent of Ogle and his co-workers and use the term fixation disparity either with central or peripheral fusion situations. The phenomenon is of the same general character regardless of whether there are central fusion clues in the test situation or not, and it is generally undesirable to introduce unnecessary new terminology in the interest of possible semantic purity.

In the middle of the range the changes in fixation disparity were almost directly proportional to the changes in prism power. The second main group, consisting of less than ten per cent of the subjects tested, showed essentially no change in fixation disparity until near the limits of the vergence range. The third group was very similar to the second group except that the third group did not show an increase in fixation disparity at one end of the motor fusion range. The fourth group was characteristic of persons with poor binocular vision and exhibited only limited amounts of fixation disparity.

Charnwood (1951) in a review of the phenomenon of inexact binocular fixation applied the term "retinal slip" to the inexact fixation exhibited by Ogle's first group while he limited the term "fixation disparity" to the inexact fixation of Ogle's second group.

Apparently on the basis of unpublished work, as he gave data for only one subject, Ogle (1950) stated that the variation of fixation disparity with forced vergence is approximately the same with any one subject regardless of whether or not the test situation allows central as well as peripheral sensory fusion. However, his scatter plot of fixation disparity with peripheral fusion only and of fixation disparity with central and peripheral fusion, using a fixed convergence demand of 2.5 meter angles, indicates that there were two groups included in his 24 inexperienced subjects. One group showed approximately the same amount of fixation disparity under the two conditions while the second group showed only small central fusion fixation disparities even though they had fairly large peripheral fusion fixation disparities. Ogle did not state whether these 24 subjects had good binocular vision.

Ogle, Mussey, and Prangen (1949) found that there was significantly less change in fixation disparity with forced vergence as the fusion details of their test situation were placed closer to the center of the visual field. Thus their work indicated that the changes in fixation disparity that occur with changes in vergence may be markedly different depending on whether or not there are central as well as peripheral fusion clues. They did not use any targets which allowed central fusion, however.

Jampolsky (1956) stressed that fixation disparity situations that employ only peripheral fusionable detail are highly artificial. Fixation disparity targets should include foveal as well as peripheral fusionable material.

Shepherd (1951) attempted to study the relation between fixation disparity and peripheral sensory fusion by using discs of varying diameters as fusion targets, fixation being at the center of the target disc. He concluded that "there was no relationship whatsoever between fixa-

tion disparity and the size of the targets, much less a direct one." However, he listed fixation disparity values far in excess of the generally accepted size of Panum's areas for the peripheral area of the retina supposedly being used for fusion.

PHOTOGRAPHIC STUDIES

Stewart (1951), using a photographic technique, determined the difference between the convergence stimulus and the actual convergence of the eyes, the fixation disparity, for various targets and target distances. Even when he used a crosshair for binocular fixation, convergence fluctuations of over a degree occurred without any awareness of diplopia. Similar astonishingly large fixation disparity values were obtained using a diamond as the fixation target. Stewart pointed out the discrepancy in the maximum amount of fixation disparity obtained by Ogle's subjective technique and Stewart's photographic one, and stated that further experimentation is needed.

Clark (1936) reported an experiment in which he took photographs of the eyes as fixation was shifted back and forth between two objects in a fused stereoscope picture. He rejected the "law of corresponding points" because he found fixation disparity magnitudes of as much as 2.4 degrees while the object was reported as single. He stated that any point of the retina within one to one and one-half degrees from the center of the fovea may be used for fixation.

In a personal communication, Hebbard (1955) reported that he had made photographic measurements of the right eye component of fixation disparity with three subjects and that he found surprisingly large amounts of fixation disparity.

THE UNIOCULAR COMPONENTS

Ogle (1950) in discussing the division of fixation disparity between the two eyes stated that some individuals have most or all of their fixation disparity in one eye, the other eye fixating exactly, while with other individuals fixation disparity apparently is approximately equally divided between the two eyes. Ogle pointed out that whenever the two retinal images stimulate disparate points and sensory fusion nevertheless occurs, the two different primary subjective visual directions of the stimulated areas in the two retinas must in some way be "fused" to a single directional percept.

Ogle noted that the two possibilities which may occur are that "either (1) one of the two monocular primary subjective directions must disappear, and the visual direction of the fused image must be that of the other eye, or (2) both of the primary subjective visual directions

of the monocular images must lose their fundamental identity and be replaced by a new subjective visual direction, which lies between the two primary monocular directions."

Ogle stated that both of these possibilities occur, the first with persons having a marked ocular dominance. However, Ogle has published data for only one subject, himself. He is an example of the first possibility, having a strong ocular dominance and apparently having the subjective direction of fused disparate images coincide with the primary subjective visual direction of the dominant eye.

Walls (1951) in developing his theory of ocular dominance concluded that for an individual having ocular dominance, fixation disparity should reside entirely in the non-dominant eye. Walls stated that the essence of motor ocular dominance is that the perceived direction of a perceptually single binocularly viewed object is determined by "the employment of the record of the innervations to the muscles of one eye only," the dominant eye. He believed that such ocular dominance exists in a large majority of normal individuals.

FIXATION DISPARITY WITH PROLONGED VERGENCE

Ogle and Prangen (1953) utilized their concept of fixation disparity as an indication of the stress on motor fusion to study vertical vergence movements. They determined the changes that occur in vertical peripheral fusion fixation disparity upon the wearing of vertical prisms. While they found they could induce vertical fixation disparity by forced vertical vergence, surprisingly they also found that with some subjects the induced vertical fixation disparity would reduce to its original value as the subject continued to wear the prisms.

Similarly, the vertical heterophoria measured through the vertical prism would return to the original heterophoria in these subjects. Thus, apparently, the tonic innervation to the oculorotary muscles is in some manner changed by forced vergence movements. If fixation disparity is a measure of the stress on the vergence function, the change in the tonic innervation has allowed a decrease in the fusional vergence necessary to maintain sensory fusion. The change in the heterophoria, the fusion free position of the eyes, is also an indication that the demand on the vergence function was in some manner reduced.

Morgan (1947) studying horizontal fusion movements and Ellerbrock (1950) studying vertical fusion movements both found that the fusion free position of the eyes changes following forced vergence movements. Ellerbrock found that this induced residual tonicity persisted for a period of up to 30 minutes following the wearing of vertical prisms for two and one-half hours.

Ogle and Prangen noted a similar phenomenon with some patients. Upon wearing of prisms which correct their previous vertical heterophoria, these patients soon show a change in the heterophoria measured through the prisms back to the original vertical heterophoria. An example of this phenomenon was the patient reported by Ogle and Prangen who originally had a heterophoria measured by the Maddox rod technique of 2Δ left hyperphoria. After wearing fit-over prisms attached to her spectacles of 2Δ divided between the eyes for three hours, the hyperphoria measured through the prism was again essentially 2Δ left hyperphoria. Thus the true fusion free position of the eyes was now 4Δ of left hyperphoria, 2Δ being corrected by the prisms. The fit-over prisms were then increased to 4Δ. After she had been wearing this prism amount for several hours the measured hyperphoria was again 2Δ left hyperphoria. Ogle and Prangen concluded that with patients who show this compensation phenomenon there must be some mechanism which acts to maintain the same effective heterophoria.

Mitchell and Ellerbrock (1955) investigated the adaptation phenomenon during forced convergence and divergence. They used a target for measuring fixation disparity which had only peripheral clues for horizontal motor fusion. They found that compensation or adaptation as indicated by change in fixation disparity occurred with forced divergence but not with forced convergence. They suggested that this difference between forced convergence and forced divergence may indicate that fusional convergence is "controlled in a different way than fusional movements in other directions."

The occurrence with some patients of a change in the measured heterophoria upon the wearing of prisms has apparently been noted frequently by optometrists and ophthalmologists, although there are few references to this phenomenon. Schubert (1943) found such changes with both horizontal and vertical heterophorias. Elvin (1954) found this compensatory phenomenon to vertical prism prescribed for the correction of hyperphoria in only 2 of 27 patients. However, he used as the criterion for the prescription of vertical prism, the hyperphoria measurement obtained with the Turville infinity balance test. This procedure measures the vertical vergence needed to reduce to zero vertical peripheral fusion fixation disparity.

RECENT ARTICLES

Arner et al. (1956) concurred in Ogle's conclusion that a relationship probably exists between the character of the fixation disparity exhibited by a subject and the presence or absence of visual asthenopia. Arner et al. concluded that subjects who exhibited a fixation disparity

curve characteristic of Ogle's second group reported less visual asthenopia. The same tendency was also indicated for those subjects who had a wide range of motor fusion during which fixation disparity did not exceed ten minutes of arc.

The quantitative relationship between fixation disparity and fusional convergence was utilized by Christoferson and Ogle (1956) to study the accommodative-convergence reflex under conditions of binocular fusion.

The author of the present article is of the opinion that in the next few years articles by many experimenters will appear utilizing fixation disparity to investigate the validity of some of the concepts of clinical optometry. Fixation disparity is becoming an important tool factor in physiological optics and clinical optometry instead of being only an interesting phenomenon.

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DIGEST

PROFESSIONAL PRACTICE MANAGEMENT

The new book *Professional Practice Management* by B. C. Egerter, D.S.C., F.A.A.C., was published in May. Dr. Egerter is a chiropodist who has become an authority on various aspects of practice administration. While this new book was written for chiropodists much of his material will be of value to optometrists. This text offers to every professional man in the health field a format for his own success. In its over 500 pages, it gives proved, practical answers to countless day to day problems of building and conducting a successful practice. It offers mature counsel on perfecting service to patients and on managing business aspects ranging from selecting a location through details of laying out and furnishing an office, choosing associates and assistants, designing stationery and developing office routine, into considerations of professional attitude, handling of fees, collections and accounting.

The book is well illustrated with over 100 photographs of up-to-date offices and treatment rooms, needed forms and records—all easily adapted to individual needs. The book is published by the Pageant Press, Inc., 101 Fifth Ave., New York City 3. $15.00.

CAREL C. KOCH

LENTICONUS‡ AND ITS RELATIONSHIP TO THE ACA RATIO*

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INTRODUCTION

The concept of the stable or innate ACA ratio has been challenged from time to time. It is thought by many that the ACA ratio is variable from day to day or year to year and that it is probably a learned function. While it is not the purpose of this paper to deliver the final argument in this discussion, it is necessary for both schools of thought and for the understanding of this paper that the concepts involved are clear.

At a given time or during a given test, a relationship can be demonstrated between the diopters change of accommodation and the prism diopters change of convergence under dissociation. This is not subject to much argument and is the physically measurable aspect of the ACA ratio. Because of the ease of using functional terminology, the ACA ratio is usually specified as the diopters change of accommodation divided into the prism diopters of change of convergence brought about by the accommodation.

Along with the physically measurable components of the ACA goes a definite neurological activity which has not been measured directly. The ratio of the change of convergence *innervation* divided by the change of accommodation *innervation* in the absence of fusion, is the ratio which is implied when we say the ACA ratio appears to be innate and constant. There is evidence[1, 2] that the innervations to accommodation and convergence are simultaneous and cannot be a reflex from one to the other. Thus, the accommodative-convergence *reflex* is probably inappropriately named.

The manifest or measured ACA ratio is a function not only of the innervations involved, but also of the psychophysical problems of measuring accommodation and convergence and the physiological variables

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‡Lenticonus as used in this paper is the relatively higher surface curvature of the center of the lens as compared to the periphery of the lens of the human eye.

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in the function of the motor mechanisms of both accommodation and convergence. For example, the accommodative motor mechanism may be subjected to a drug such as atropine which reduces the lens change per unit of innervation coming to the ciliary muscle. This will increase the apparent ACA ratio because more innervation will be needed to produce a one diopter refractive change, and due to the neurological association a correspondingly increased innervation to the convergence motor mechanism will occur.

Because of our inability to measure the neurological output to accommodation and convergence in the human, the advocates of the stable ACA ratio have had to be content with the use of qualifying words "appears to be," even though the evidence in support of a stable ACA ratio is quite convincing. On the other hand, the advocates of the variable ACA ratio have attacked the concept because clinical data are quite variable. Clinical and even laboratory data are dependent on the optical changes in the convergence-accommodation mechanisms which are very difficult to evaluate instantaneously, the more so the less skilled the subject at making psychophysical judgments and the clinician at conducting a psychophysical experiment (i.e., taking optometric findings).

Since there may be several factors, besides the basic innervation, which dictate the ACA ratio that a given person demonstrates, it was the purpose of an earlier paper[3] to see if the viscosity of the lens (resistance to change) could be correlated with the ACA ratio. The results indicated that an increased lens viscosity did not correlate with a high ACA ratio.

This paper is intended to try to correlate the ACA ratio with the "efficiency" of the lens for increasing its power, to see if an accommodative mechanism which is very efficient is associated with a low ACA ratio and vice-versa. A relatively large increase in power of the lens center compared to the lens periphery would be taken as highly efficient while an overall spherical change would be taken as inefficient. This is based on the idea that confining the increase in curvature to the portion of the lens exposed by the normal pupil would produce the most change in refraction with the least shift of lens contents, and presumably the least ciliary effort.

APPARATUS

The experimental apparatus consists of a specially built slit lamp designed as a Badal optometer with four fine horizontal hair lines for the stimulus to accommodation (see Figure 1a). A single lens reflex camera was arranged as shown, to photograph the slit lamp view of the lens. Because of the intense light from the slit lamp needed for photography, the subject could not see the line targets well enough to control

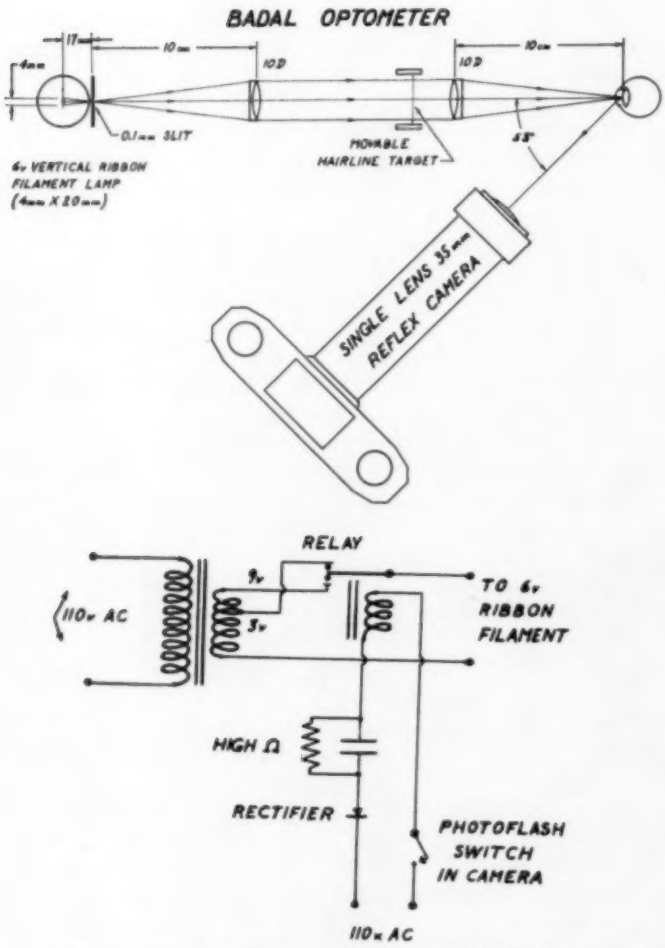

Fig. 1. (a) Top. Camera. (b) Bottom. Reduced voltage.

his accommodation. Figure 1b shows how the voltage across the lamp was reduced for viewing and was then raised to an overvoltage for about 1/10 of a second while the photograph was being taken. The control of the flashing relay was via the condenser to the switch built into the shutter mechanism in the camera. The picture was taken at an effective aperture of about f 4.5 and a shutter speed of 0.1 second on Eastman

tri X panchromatic film. The subject's pupil was dilated with 10% ophthalmic neosynephrine emulsion following ½ % pontocaine.

DATA

The negatives were enlarged onto photographic paper set at 53° to the light which produced an approximate correction for the fact that the camera was set at 53° to the plane of the slit lamp beam. The focal length of the enlarger lens was 135 mm.: the distance from the film to the center of the paper plane was 79 cm. The photographing lens consisted of the camera lens of 100 mm. focus and a 75 mm. focal length enlarging lens attached to it and turned so as to receive properly from its back side the diverging light from the eye. The two lenses on the camera thus functioned as a unit, with parallel light traveling between them.

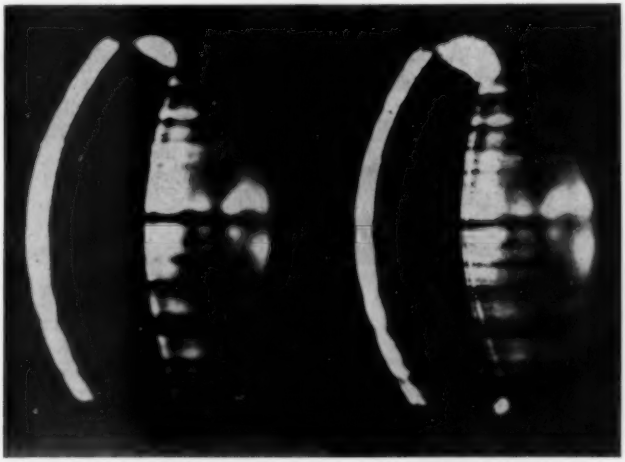

Fig. 2. Slit lamp view of cornea and lens.

Figure 2 shows the slit lamp view of the cornea and lens when relaxed and when accommodated after correcting the image to the way it would have appeared if viewed at a right angle to the line of sight of the subject. For this print the camera optics were used, and the film image was projected from the camera onto a photographic plate placed in the position formerly occupied by the eye. This gives a true correction for projected distortion. The photographic prints used for measurements were not so carefully corrected because it was felt that relative values of peripheral lens flattening (lenticonus) would serve as well, since other uncontrolled factors due to the oblique corneal refrac-

tion render the view of the lens unsuited for precise measurements of lens curvatures without rigorous mathematical corrections. Thus the data are approximate and were obtained from prints made as described in the preceding paragraph.

The measured radius of the cornea from the enlargement was compared to the radius determined by the keratometer findings. This gave the magnification ratio of the size on the photographic print to the size of the actual eye. All measurements taken from the photographic print were corrected by this magnification ratio. The corneal power was then used to calculate the actual depth of the anterior chamber and the actual radius of the front surface of the lens. These actual radii were then used in the formula

$$D = \frac{n'-n}{r} \qquad (1)$$

where D = diopters of refraction, r = radius of the refracting surface, n' is the index of the second optical medium and n is the index of the first optical medium. By using values for the lens index of $n' = 1.386$ and for the aqueous of $n = 1.336$, the refracting powers of the surface of the lens were determined.

The degree of lenticonus of the lens was represented by

$$L = D_{\text{center}} - D_{\text{edge}} \qquad (2)$$

where L is the lenticonus factor and D is the diopters of refracting power of the lens surface.

The change in lenticonus during accommodation was determined by

$$E = 1 + \frac{L_{\text{(accommodated)}} - L_{\text{(relaxed)}}}{D} \qquad (3)$$

where E is the shape factor, L is the lenticonus factor and $D = D_{\text{center accommodated}} - D_{\text{center relaxed}}$. A value of E greater than one indicates that much of the lens change occurs in the central area of the lens while a value for E of one, means that the lens changes uniformly and that no difference in general shape (e.g., spherical) exists when relaxed as compared to when accommodated. Values less than one would indicate that the lens bulges more in the periphery than in the center during accommodation.

Figure 3 shows the distribution of central lens accommodative responses of the various subjects with respect to the amount of stimulus change. The middle line shows the theoretical changes[4] in the anterior surface of the lens for the various stimuli, while the lower line shows the theoretical changes in the posterior surface of the lens. The posterior

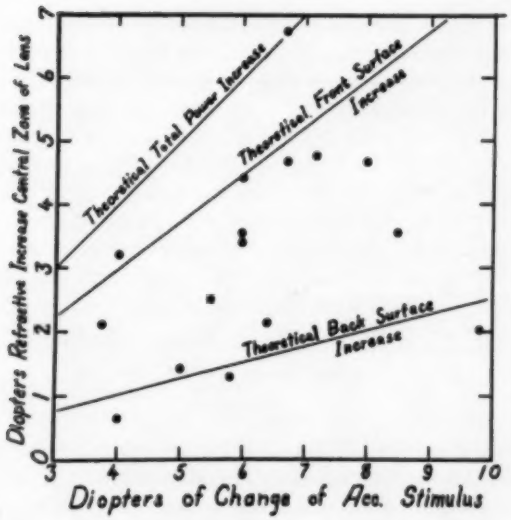

Fig. 3.

surface of the lens was not measured, being invisible at the 53° angle used, hence the points should be compared only to the middle line. Since the Badal optometer stimulus was specified from the plane of the slit image focused on the lens, the stimulus values were comparable to the diopters increase in lens power at the front surface.

The ACA ratio was determined by measuring accommodation with a coincidence optometer while the phoria was being taken. Figure 4 is a plot of the ACA ratio against the lens shape factor E for each of the subjects. The curved line (T) is supplied to show the type of relationship that might exist if the ACA ratio were to be accounted for by lenticonus. The data do *not* fit this curve.

The amplitude of accommodation was measured with a fine letter near point test card held by the subject and brought to his near point of accommodation. Scatter plots (not shown) of the E factor against the amplitude of accommodation showed no correlation. A similar comparison of E against age also showed no correlation.

DISCUSSION

In Figure 3 the majority of the data falls below the middle line. If we would shift the middle line down 0.75 diopters to allow for depth of focus, over half of the subjects will be on or above this new position of the line. Thus Figure 3 supplies a check on the excellence

of the subject's accommodative response and the adequacy of the experimental method used.

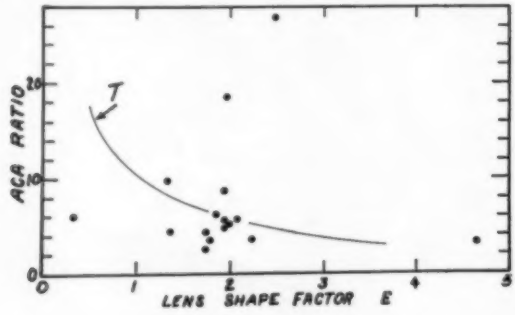

Fig. 4.

The data presented in Figure 4 show no apparent correlation. This distribution is unusual in that in this unselected group of subjects a high percentage with high ACA ratios was found. The subjects were taken from optometry classes on a volunteer basis and the student age range was from 20 to 33 with one child age 11 and myself age 38 included.

The curved line T in Figure 4 is intended only to show how the data should have lined up if we had found that lenticonus is associated with low ACA ratios, and spherical lenses, or inverse lenticonus ($E < 1$), with high ACA ratios. From these data it would appear that the accomodative motor mechanism functions equally well whether the lens changes spherically or with a steeper curvature toward its center. These data alone do not rule out the possibility that those with a high ACA ratio may have some impairment of accommodative function in the suspensory ligaments, ciliary muscle, choroid, or cilliary plexus, which resulted in an increased measured ACA ratio.

One source of error in this study was the subject's personal evaluation of when he was in focus. Since the target line was at right angles to the slit beam entering the eye, the image on his retina was composed of rays from the extreme vertical margins to the center of his optical system. Irregularities, and spherical and chromatic aberrations must so impair the image quality that a subject's accommodation probably cannot be precisely controlled. Indeed several observers reported fair images throughout the range 0-10 D. without any measurable change in lens curvatures!

Other sources of error include the difficulties encountered in the measurement of the central radius of the lens. The image of the lens,

magnified about six times as a photographic print on paper was compared with a series of circles of variable size projected by a photographic enlarger. The size of the circles was varied until one matched the curvature of the portion of the lens or cornea being measured. Such inaccuracies appear to have been held to less than 1/4 diopter refracting power of the lens.

The oblique refraction through the cornea at 53° makes an object-image calculation based on thin lens optics very inaccurate. However, since the inaccuracies would be constant in any given series of photographs, they were ignored. This may account for some of the discrepancies shown in Figure 3, although the failure on the part of the subject to accommodate for the target is the more probable source of deviation.

SUMARY AND CONCLUSIONS

Discussion was given to the importance of considering innervations instead of clinical measurements as being constant when a constant ACA ratio is being considered. Description was given of a modified slit lamp, containing an adjustable accommodative stimulus target, and a camera set up for photographing lens changes occurring during various amounts of accommodation. The shape changes of the lenses of 16 subjects were plotted as numerical values, the lens shape factor E, which are an indication of accommodative "lenticonus."

The ACA ratio was found to be unpredictably related to the lens shape factor E so that it was not possible to account for the ACA ratio being abnormally low or high as a result of an efficient or inefficient lens shape change during accommodation.

The failure of accommodative lenticonus to explain high ACA or low ACA ratios places the ACA ratio determining factor outside the dioptric mechanism. Perhaps the suspensory system or muscle system can be shown inefficient or defective, but the fact that the author in another paper[2] has failed to find abnormalities in the speed of the accommodative mechanism that could be correlated with either high or low ACA ratio, means that the probable source of the ACA ratio is the innervational association between accommodation and convergence. In other words, the peripheral mechanism of accommodation seems normal even though the ACA ratio may be extreme.

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THE OPTOMETRIST'S RESPONSIBILITY

Much has been written in the optometric literature about the optometrist's responsibility to his patient and the ophthalmogist in the field of prevention of blindness. We also find considerable literature devoted to the optometrist's responsibility to his patient and school authorities in matters relating to vision and reading problems. Industrial vision and the optometrist's responsibility to his patient and to employers in industry have been explored rather fully during the last 10 to 12 years.

Fry[1] points out that "medical men are licensed to be responsible for matters of life and death. Michaels[2] has written a series of excellent papers outlining the symptoms and disorders which the optometrist may be the first to observe during his examination of a patient.

Not only should optometrists accept responsibility for referring patients to their general practitioner or internist when symptoms and disorders indicating systemic pathology are present, but optometrists should also discuss with the patient's physician those ocular conditions calling for referral to ophthalmologists. Frequently a patient's physician is in a position to advise the best procedure to follow and referral to be made which will be most readily accepted by the patient. By close attention to such matters, optometrists may be of help to physicians in carrying out their responsibility in "matters of life and death" for their patients.

ROBERT W. TUBESING

[1]Glenn A. Fry. The Division of Labor Between Optometry and Ophthalmology. Am. J. Optom. & Arch. Am. Acad. Optom. 34.3.150-156. 1957.
[2]David D. Michaels. (1) Observation in Clinical Practice. Am. J. Optom. & Arch. Am. Acad. Optom. 34.2.59-72. 1957. (2) Nutrition, Posture, Gait, Face and Skin. Am. J. Optom. & Arch. Am. Acad. Optom. 34.3.128-136. 1957. (3) The Hands, Circulation and Nervous Systems in Optometric Practice. Am. J. Optom. & Arch. Am. Acad. Optom. 34.4.197-208. 1957.

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REFRACTION BY AUTOMATION

All presently available procedures for determining the refractive state of the human eye require the intervention of an observer. In subjective examinations we ask the patient to make the judgments, and in objective techniques, such as retinoscopy, it is the examiner who carries out observations or makes the settings. In these days of automation the question may be raised whether a completely automatic method of refraction cannot be devised.* The problem deserves consideration.

Let us for the moment restrict our discussion to the determination of the refractive error of the eye in its stricter definition, and thus leave aside the question of its modifications in the light of other findings or the patient's history. What is the role of the human observer, patient or examiner, in the refractive procedure? Can he be dispensed with

*This is not a recent idea. In Zeitschrift für ophth. Optik, 29: 148, 1941, there is a description of a device (U. S. patent No. 2,164,576 in the name of Geoffrey Collins) for essentially this purpose.

and, if so, how? Are there any obvious advantages in automatic methods of refraction?

It is usually preferable to have the patient's judgment of the effect of changing the refractive power of the eye on the retinal image. The reasons for this are complex. To begin with, the optics of the eyes are not as simple as those of a perfectly corrected Gaussian optical system. There is considerable chromatic aberration, the influence of spherical aberration varies with pupil size and to some extent with accommodation, the Stiles-Crawford effect modifies the efficiency of the rays entering the periphery of the pupil, and diffraction phenomena produce further light distribution changes in the image plane. In addition, we know that there are mechanisms in the visual system subserving contrast-sharpening functions, that the small movements during "steady" fixation influence vision and that innumerable other factors, physiological and psychological, enter into a decision of what constitutes the "clearest" retinal image, even in the absence of such complicating factors as active accommodation. For these reasons we prefer to be guided by the patient's statements, since these will presumably reflect the best integration of these effects.

Objective examination procedures, of course, provide much more limited information of the refractive status of the eye. The most universally used method is retinoscopy, but many other devices have been introduced for this purpose. They are usually called optometers. The Rodenstock refractometer is an example of such an instrument. Once it has been properly adjusted before the eye, its operation is much like that of a vertex refractionometer in that the examiner manipulates the controls until he judges the image to be clearest. This illustrates most clearly the difference between "objective" and "subjective" methods of refraction. Human observers are utilized in both cases, but in the "objective" methods it is the examiner who makes the judgment. It is not implied that subjective methods rely entirely on the patient's evaluation, nevertheless the critical judgments made during a subjective examination are those of the patient.

There is a considerable difference, however, in the kind of evaluation made by the examiner and by the patient. The patient's judgment will integrate a great number of factors of his own visual system. An examiner's judgment on the other hand will be built on purely optical observations and superimposed on these will be factors involving his own skill and experience. Often the latter type of examination is preferred, as for example in the case of children, illiterates, the hard-of-hearing, and some kinds of neurotics.

In the use of the retinoscope, such factors as the examiner's evaluation of the pupil size, spherical aberration, color of the reflex, presence of non-uniformities in the reflex, etc., as well as his previous experience relating retinoscopic determination to other findings, will enable him to obtain a retinoscopic measure of the refractive status of the patient's eye which is considerably more valuable than a purely photometric measure of the change in light entering a peep hole as a function of retinoscope angle and spectacle lens. This is the essence of the problem of automatic refraction: there is no insuperable difficulty in building a machine to take the place of a retinoscope and displaying its setting on tape, on a oscilloscope or printing it on a record form, but such a machine will operate on a level of complexity of decision-making several levels below that of a skilled refractionist using only "objective" methods of refraction.

At present we would be hard put to spell out specifically and quantitatively the factors which the optometrist integrates into his decision, but if a research program were instituted to this end, usable approximation could no doubt be evolved which would considerably reduce the disparity between man and machine.

In one aspect at least a machine is theoretically much superior: the time factor. It seems not at all impossible to obtain 60 or more determinations of the refractive state of the eye per second with a machine, while even a skilled refractionist will require a minimum of several seconds for a single determination. This may appear a trivial problem in clinical practice, but for many investigations, the time factor is quite important.

GERALD WESTHEIMER*

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QUALITY SUNGLASSES AND THE PROFESSIONAL OPTOMETRIST

The present wide use of plano sunglasses by millions of persons prompts the inquiry as to why optometrists frequently fail to identify themselves with this phase of eye care. Many optometrists permit their patients and their friends to be served with these essential aids to visual comfort through very irresponsible channels, and in doing this they are overlooking an opportunity for real service to many emmetropic as well as ametropic patients.

The fact that inexpensive sunglasses are on sale in many types of retail outlets has been one of the reasons why optometrists in professional practices have developed an antipathy for dispensing real first quality sunglasses. They feel that in some way they are competing with retail merchants when they do, and that this may affect their professional standing in their communities.

Another factor that has discouraged professional optometrists from dispensing quality sunglasses has been the fact that until recently, they had no ethical way of letting their patients know that such aids to comfortable vision were available in their offices.

Actually optometrists who dispense first quality sunglasses are not in a competitive position with the shopkeeper who sells inexpensive sunglasses as merchandise. In the first place, optometrists have the knowledge to judge the quality of absorption lenses and to properly advise patients on this quality as well as the absorption value of the lenses. In addition, optometrists have the ability, equipment and technical skill necessary to properly fit and adjust sunglasses frames to give the patient the wearing quality all naturally desire. These are services not available where sunglasses are merely sold as merchandise by untrained salespeople.

With regard to the second point, today many optometrists have a dispensing room, or at least a dispensing area, in which spectacle frames are shown to patients in private. There is no ethical reason why a small selection of quality plano sunglasses should not be shown to patients. This would have a two-fold effect. For ametropic patients it would emphasize the need for an absorption pair of prescription spectacles, and for the emmetropic members of the family it would point up the way for these patients to secure quality plano sunglasses that properly fit the face and head. This is a truly optometric professional service many individuals would appreciate and be willing to pay for, and is one which may easily be supplied by ethical professional optometrists everywhere.

CAREL C. KOCH

SPECIAL REPORT

OPTOMETRY, OPHTHALMOLOGY AND DISPENSING OPTICIANRY*

Ernest A. Hutchinson†
Los Angeles College of Optometry
Los Angeles, California

There is no scientist whose prime allegiance is to optometry who commands more respectful attention in optometry, ophthalmology and scientific circles generally than Glenn A. Fry, director of the School of Optometry, The Ohio State University. Hence what he has to say on "Interprofessional Relations in the Design of Eyewear," (the subject of a Special Report in the April, 1957, issue of the AMERICAN JOURNAL OF OPTOMETRY AND ARCHIVES OF AMERICAN ACADEMY OF OPTOMETRY) is of more than ordinary interest.

In addition to the recent change of policy of the American Medical Association, in effect declaring it no longer unethical for an ophthalmologist to profit from the sale of spectacles he prescribes, the impact of the emphasis upon style in spectacles has interjected a new and exceedingly complex factor into the area of visual care.

Some years ago in conversation with a leading authority in the field of visual physiology we agreed that the physician who was an expert in treatment and surgery of the eye, seldom enjoyed the tedium of routine refraction. Similarly we have known skilled optometrists who abominate the complications of the fitting table. It may be distaste for the sales features or merely that they are mechanically inept, their fingers all thumbs.

Incident to the introduction of "styles in eyewear" has been a marked improvement in the attitude of the public to the wearing of spectacles. However, the exceedingly wide range of choice and the feminine concern with such matters as shape, decoration, color harmony as affected by facial features, complexion and wardrobe complicates the matter of dispensing to the Nth power. The individual office practitioner in optometry or ophthalmology is handicapped in competition

*A discussion of some of the points raised by Dr. Glenn A. Fry in his paper "Interprofessional Relations in the Design of Eyewear," Am. J. Optom. & Arch. Am. Acad. Optom. 34.4.212-220, 1957. Submitted on May 22, 1957, for publication in the June, 1957, issue of the AMERICAN JOURNAL OF OPTOMETRY AND ARCHIVES OF AMERICAN ACADEMY OF OPTOMETRY.
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with the dispenser and the commercial optometrist. In the office of one of the latter I counted in excess of two hundred frames on display. No amount of theorizing about the advantage of *one man doing the whole job*, whatever may have been the case in times past, can avoid the conclusion that the man who undertakes to guide his patient in selection of eyewear to meet the current mode or milady's taste, is putting himself in the class of Pere Westmore. At the Optical Fair, Westmore is to talk on "beauty secrets for women," including such subjects as hair styling, cosmetics, wearing apparel, and of course "the proper style and shape of frame for each facial type, hair and skin coloring and other features which can be highlighted with stylish spectacles."

As noted, there is a close resemblance between the attitude of many young eye-physicians to refraction and that of some optometrists to dispensing. It is not so much one of regarding it as degrading as irksome, exacting, and time consuming. However, to the new licentiate; refracting to the eye-physician and dispensing to the optometrist, each is an essential source of income.

The busy ophthalmologist is under no medical compunction to refract his patients. He is frequently served by reliance upon the findings of a physician or optometrist associate who specializes in refraction. If in turn their combined skills are furthered and completed by a competent dispensing optician the situation may approach the ideal. Such team work would have many advantages and none of the disadvantages of the one man idea. In practice the idea that one man should do the whole job is more honored in the breach than in the observance. In the busy office of either ophthalmologist or optometrist, for years unlicensed persons have performed such duties as refracting in the former, orthoptics and dispensing in the latter. Fry's suggestion that optometrists are obligated to accept referrals for fitting eyewear seems somewhat unrealistic. If as he says that ophthalmologists training is too costly to be wasted on dispensing, the optometrists is only slightly less so. Furthermore when optometrists were the only opticians available to fill oculists prescriptions, the latter labored unceasingly to create the impression that the optometrist was an inferior in the field of refraction. Not to be outdone, the optometrist not infrequently took over the physician's patient when the latter was dissatisfied with the physician's prescription. In the writer's judgment, more need not be said to indicate that the idea of optometrists dispensing for ophthalmologists is unnatural and usually unworkable. Doubtless an important factor inducing the ophthalmologist to enter the field of dispensing was loss of the kick-back or rebate from the dispenser, which until declared illegal and adjudged so in the courts, was quite general.

It is a fair assumption that the endeavor to recoup this loss by a corresponding increase in examination fee was not well received by the public. The promised reduction in the price of glasses did not materialize, in fact, the superior sales ability of the dispenser whereby he was able to encourage the patient to purchase an adequate array of spectacles for all occasions was at once the envy and the worry of the physician referring the case.

As to higher fees for service it can only be said that it is much easier to obtain an adequate fee by including it in the price of something tangible than to collect it as a separate item. This too, although not generally acknowledged, is a compelling reason why optometrists have insisted in doing their own dispensing. In the British House of Lords the late Lord Charnwood, himself an optometrist, eloquently maintained that there was no validity to the argument that the optometrist should do his own dispensing.

This is an age of specialization. Quite obviously the surgeon who operates frequently is likely to be more skilled than the one who operates only occasionally. By the same token the ophthalmologist or optometrist who spends all his time refracting, using that term in its widest connotation, should excell in optometry. Logically it follows that the man whose sole interest is dispensing has an edge on the ophthalmologist or optometrist or lay person who is a part time dispenser.

Steering of patients by dispensing opticians to ophthalmologists is precisely what should be expected. Optometry has no cause for complaint in the premises, unless its competency is called in question. If the dispenser catered to patients of the optometrist also there would be no incentive for discrimination.

To sum up these comments. Maximum economy and efficiency in providing for the visual and ocular needs of the public naturally calls for three fairly distinct types of specialization: (1) Treatment and surgery. (2) Refraction and orthoptics. (3) Dispensing and adjusting. Maximum efficiency and economy will not and cannot be achieved unless and until there is established the closest cooperation between the three constituent groups. Such cooperation well might obtain in the area of preparation for practice. There are a number of very capable ophthalmologists who started their professional careers as optometrists. Their practice of optometry enabled them to earn a livelihood while establishing a practice as pathologists. Similarly very many opticians have continued their studies and qualified as optometrists, benefitting greatly by their qualifications as dispensers. Such progress should be encouraged, but standard practice should aim at separation of the field of eye care

into the three groups which by their concentration, each to its own area, would be free to cooperate without restraint with the other two components. Is that idealistic? The ideals of today are the realities of tomorrow!

CURRENT COMMENTS

Terry Judith Parkins
Editorial Assistant

Optometrists will confer a favor by sending news items of general interest for this department; such as relate to new instruments, clinical techniques, education, visual health and optometric legislation and organization.

FEE INCREASE OVERDUE

There is a certain resentment among optometrists when the subject of fees is mentioned. We do not know why this condition exists but we are aware that this is the case. In spite of this we owe it to the more than 7,000 readers of this publication to call certain, at times, unpleasant facts to their attention. One of these is, that if in 1957 the total individual fee received from each patient is not more than 20 per cent higher than the fee for similar service was in 1947 that you are now in a poorer position than you were then.

Here is what a financial expert has to say on this subject.[1] "On the domestic front the cost of living continues to forge ahead and the dollar's purchasing power continues to shrink in corresponding degree. For April the Labor Department's consumer price index rose 3/10ths of 1% to 119.3% of the 1947-49 base. This was a new all-time high for the eighth consecutive month and a fresh peak is officially predicted for the month of May. The April rise will up the pay about 2 cents an hour of an estimated 1.4 million workers, chiefly in the auto and farm equipment industries, whose wage contracts contain escalator clauses. Increased wages mean increased costs and resultant higher prices. The old wage-price spiral is not only still with us but is continuing to gain momentum."

Actually—because our average optometric fees were so low in 1947, we should move to a much higher plateau than one merely 20 per cent over the 1947 figure—whatever that was in your office. To enable us as a professional group in the healing arts field to continue to offer the public the finest refractive care, we must now get our fee structure in line with the economy of the country. For many optometrists this means a very substantial increase in fee charges and for all it means an upward swing in fees.

[1]June 3, 1957, Market Report, Reynolds & Company.

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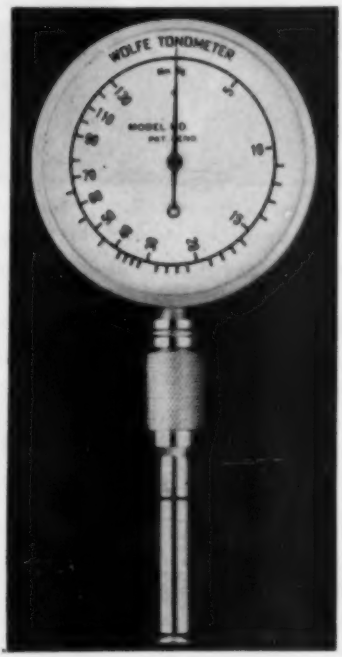

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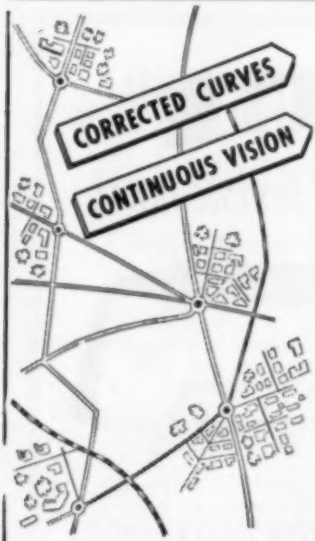

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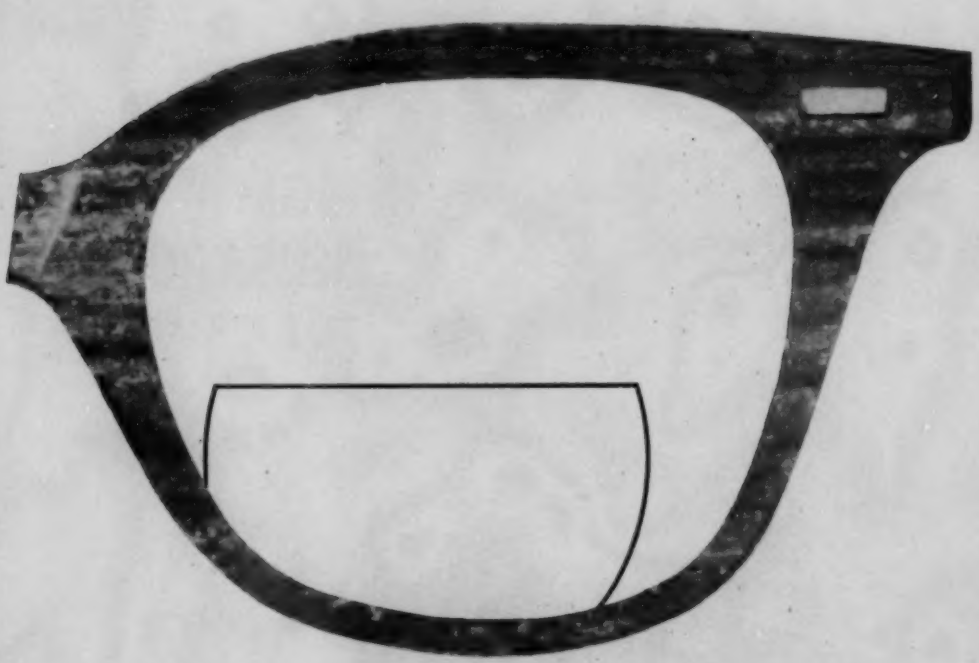

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